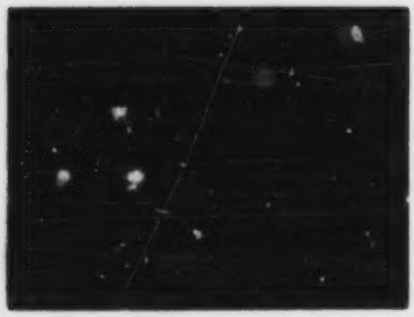
Monenco

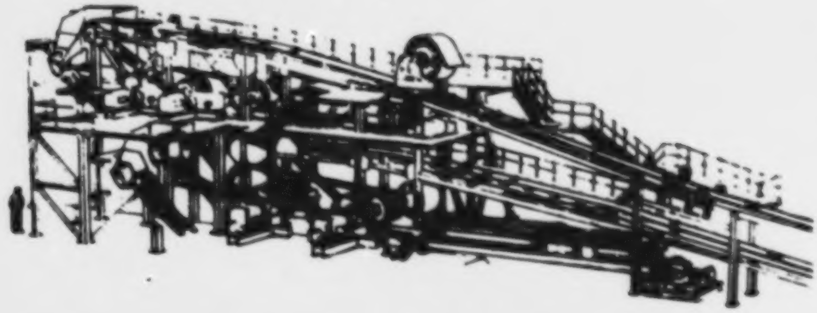
STATE OF ART REVIEW OF SAFE UNDERGROUND COAL & WASTE TRANSPORT SYSTEMS

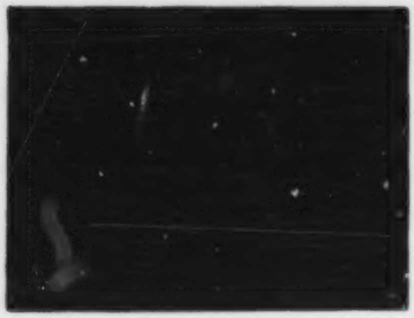
FINAL REPORT

BY

MONENCO CONSULTANTS LIMITED







FOR

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY
ENERGY MINES & RESOURCES CANADA

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CANMET SCIENTIFIC AUTHORITY: MR. G. HASLETT

MARCH 1985

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Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines & Resources Canada

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DSS 8115-9

Mr. G. Haslett
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Dear Mr. Haslett:

Underground Coal and Waste Transportation Systems
DSS Ref. 14SQ.23440-4-9099

We have pleasure in submitting our final report for the above project, in twenty bound copies each of which includes an executive summary in English and French.

The report, which includes the comments made during the review of the draft report, comprises seven parts.

Part 1 provides the background to the study; Part 2 deals with the study methods; Part 3 describes the transportation systems in current use; Part 4 presents the preliminary system selection and a more detailed description of the selected systems. These systems are analyzed and their maximum performance levels stated in Part 5. Parts 6 and 7 respectively present our conclusions and recommendations.

We have also included in the Appendices, relevant technical references and representative technical papers.

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We have found the work on this project extremely interesting and trust that the report will be to your satisfaction. We shall be pleased to answer any questions arising from the report.

Yours very truly,

MONENCO CONSULTANTS LIMITED

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LIMITED

EXECUTIVE SUMMARY

(English)

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This report was commissioned by the CANMET Coal Research Laboratory in Sydney, N.S. Its objective was to review the available information relating to the transport of coal and waste from underground mines and to provide a state of the art summary of systems suitable for use in underground coal mines.

The summary was to address:

(1) Secondary systems with capacities from 350 to 600 tonnes per hour, capable of operating on gradients up to 25%.

(2) Primary systems with capacities from 1400 to 2400 tonnes per hour, capable of operating on gradients up to 25%.

(3) Surge capacity in the primary system of three times peak loading for five minutes duration.

(4) Reliability, availability, safety, and adaptability to remote monitoring and control.

(5) Capital, operating, maintenance and replacement costs.

(6) Maximum attainable level of performance.

System design and the transportation of men and materials were specifically excluded from the study.

2.0 STUDY METHODS

Information was gathered by (i) literature search using North American and European data bases and the CISTI Mining Library; (ii) requests to foreign organizations; (iii) requests to equipment manufacturers, and (iv) data from Monenco's in-house resources.

The bulk of the information came from the literature search (200 relevant papers) and the manufacturers.

Data from conveyor manufacturers such as Cable Belt, Huwood, Dowty Meco, Anderson Strathclyde and Krupp, and from mine operators using slurry pumping systems such as Consolidation Coal and Westar Mining were most useful.

3.0 GENERAL TRANSPORT SYSTEMS

A review was made of the transport systems in current use in underground mines for the transportation of coal and waste. Six groups were identified:

(1) Rope haulage systems;
(2) Locomotive systems;
(3) Trackless haulage systems;
(4) Conveyor belt systems;
(5) Hydraulic systems;
(6) Pneumatic systems.

3.1 ROPE HAULAGE

This is the oldest form of coal transport currently in use and utilizes steel cables to haul mine cars or tubs on rail tracks. The system has limited capacities, dependent particularly on gradients and has a high maintenance cost. For these reasons, it is almost obsolete for coal transport except in a few old mines. Its main continued use is for the transport of men and materials.

3.2 LOCOMOTIVE HAULAGE

Running on rail track, locomotives can be powered by diesel, battery, trolley electric, battery/trolley, and compressed air.

The compressed air locomotives have limited power and range and are only used in a few very gassy mines in Europe.

Drive powers up to 300 kW are available for diesel and trolley locomotives, and up to 150 kW for battery locomotives.

Standard forms of locomotive can only safely operate on gradients of less than two degrees (1 in 30), but economically are usually limited to a maximum of one degree (1 in 60).

New developments are taking place which allow locomotives to work on much steeper gradients. These are:

(1) Adhesion wheels allowing operations up to three degrees (1 in 19).

(2) Captive Rail systems with which gradients up to 14 degrees (1 in 4) are possible.

(3) Rack Drive which can operate on gradients up to 18 degrees (1 in 3).

To date, none of these new locomotives have sufficient power to haul economical loads for coal transportation on steep gradients.

The latest development in coal haulage by train in Europe is the 'Super train'. A unit train of 2 x 300 kW trolley locomotives permanently coupled to 30 - 30 tonne mine cars which handles 10,000 tonnes per day over four kilometres.

In Europe, locomotives are considered to have advantages over belt conveyors if the haulage distance is over four kilometres. In the USA, the comparable figure is seven kilometres.

Locomotive systems are currently operating under remote control or full automatic control in many countries of the world.

3.3 TRACKLESS VEHICLE HAULAGE

These are rubber tired, free steered vehicles which take two forms--vehicles which load, haul and dump (LHD), and those which only haul and dump. The former have capacities up to 15 tonnes but for economic reasons only operate over short distances (300 m) whilst the latter have up to 30 tonne capacity, and whilst they can operate over longer distances, do not provide economic high capacity continuous haulage.

3.4 BELT CONVEYORS

There are three drive systems which are now capable of handling high outputs on gradients. These are:

(1) Booster or linear drives using standard equipment which are located within an existing conveyor and transmit additonal power to the main conveyor through friction between conveyor belts. These drives reduce belt tensions and allow higher capacities with lower specification and hence cheaper belting.

(2) High horsepower large diameter drum single drives using steel cord belting to be able to safely transmit the high tensions required. The steel cords are embedded in the belt and give great strength, but also high cost.

(3) Cable Belt conveyors in which the conveyor belt is carried on two separate steel cables through which the drive power is transmitted. The belt does not, therefore, have to handle the high tensile stresses and is of lower specification though of special construction.

Booster driven conventional fabric belt conveyors are operating with drive units up to 560 kW and up to five units in a conveyor (2000 tph). The largest underground steel cord and cable belt conveyors have recently been installed at the new 10 Mt/year Selby mine in the U.K. The main characteristics are:

	Length (km)	Lift (m)	Capacity (tph)	Power (kW)
Steel Cord	15	990	1830	10100
Cable Belt	15	990	1830	8750

Developments in the use of aramides in conventional solid woven fabric belting are giving belt tensile strengths approaching those of steel cord belting, for considerable savings in weight, and operating and capital costs. These will extend the application of belt conveyors.

Although belt conveyor systems present a potential fire hazard, the use of fire resistant belting and the development of safe and reliable systems for monitoring and remote control of conveyors is leading to their increased safe use underground for the transport of coal and waste.

3.5 HYDRAULIC SYSTEMS

Systems using water as the transportation medium fall into four categories:

(1) Gravity systems relying on the use of gradient (minimum 4°) to transport a coal/water mixture in open plastic lined flumes. (Steel lined flumes need a 7° gradient).

(2) Air Lift systems in which compressed air is injected into a pipeline, and lift induced into an agitated coal/water mixture.

(3) Hydrohoist systems where coal is batch loaded into a pipeline containing a moving high pressure stream of water.

(4) Slurry pumping systems in which the coal/water slurry passes directly through the pumps.

None of these systems are in widespread use but in the USSR, Japan and China, are handling several million tonnes of coal per year.

The only system of potential interest to the underground mines is the slurry pumping system. These are in use currently in Canada and USA handling around 900 tph through a 300 metres head. In the USSR, capacities exceed 1000 tph over 400 metres lift.

3.6 PNEUMATIC SYSTEMS

These have been more generally used to transport waste for backfilling in the mine. Recent uses, however, include the use of low pressure, high volume air systems to hoist coal through mine shafts to augment shaft capacity. System capacities are, however, low (400 tph) and limited to vertical lifts of 300 metres.

4.0 PRELIMINARY SYSTEM SELECTION

The secondary and primary transportation systems are required to meet certain criteria ('musts'). For the secondary systems, these are a capacity of 350 to 600 tph, the ability to operate on a 25% gradient and over a distance from 200 metres to 2000 metres.

For the primary system, the critical factors are: capacity 1400 to 2400 tph; grade 25%; length up to 10 kilometres and ability to negotiate 45 degree bends (Fig. 4-1).

Tables 4-1 and 4-2 indicate how each transportation system meets these criteria for the secondary and primary systems respectively. Any system which fails to meet one of the criteria ('NO') is automatically eliminated from consideration.

Examination of Table 4-1 shows that only belt conveyor systems and hydraulic systems meet the criteria for secondary conveyors.

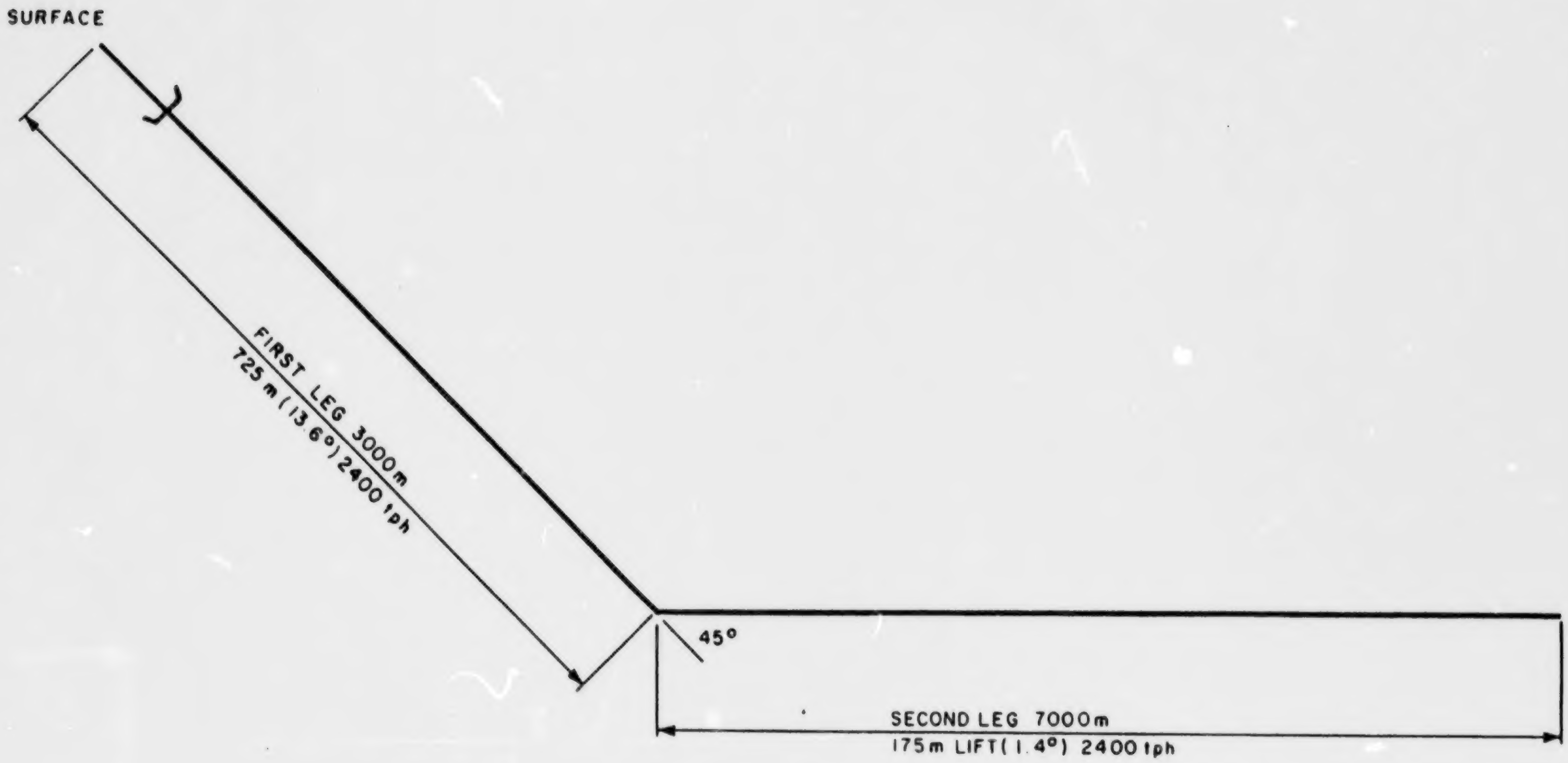

FIGURE 4-1 SCHEMATIC LAYOUT OF PRIMARY TRANSPORT SYSTEM REQUIREMENTS

TABLE 4-1

Secondary System Capabilities (MUSTS)

	Capacity (600 tph)	Gradient (25%)	Distance (max 2 km)
Rail			
- Diesel	Yes	No	Yes
- Battery	Yes	No	Yes
- Trolley Wire	Yes	No	Yes
- Trolley/Battery	Yes	No	Yes
- Compressed Air	Yes	No	Yes
- Rack Drive	Yes	No	Yes
Rope Haulage			
- Direct	No	Yes	Yes
- Endless	No	Yes	Yes
- Main & Tail	No	No	Yes
Conveyors			
- Steel Cord	Yes	Yes	Yes
- Cable Belt	Yes	Yes	Yes
- Booster Drives	Yes	Yes	Yes
- Conventional	Yes	Yes	Yes
Hydraulic			
- Gravity	Yes	Yes(-)/No(+)	Yes
- Slurry Pump	Yes	Yes	Yes
- Air Lift	Yes	Yes	Yes
- Hydrohoist	Yes	Yes	Yes
Pneumatic	No	Yes	Yes
Trackless Vehicles	Yes	No	No

NOTE: (1) Must also be compatible with primary system.
(2) A 'NO' in any category eliminates the system.

Similarly for the primary systems, Table 4-2 indicates that again only belt conveyor and hydraulic systems are suitable.

Part 4 of the report looks in more detail at these two systems.

5.0 SYSTEM ANALYSIS

Two problems were evident when the analysis was made of the suitability of the selected systems for application to underground undersea coal mines. These were:

(1) The maximum tonnage rate specified for the study (2400 tph) was high, even by today's new mine standards. (Selby 1850 tph; Lingan Phalen 1800 tph). This level presented capacity problems in certain conditions, and indicated that such a rate was at the current limit of technology.

(2) Details of a specific site, feed rates and locations, lengths, gradients and operating schedules are necessary to enable a meaningful comparison and ranking of each system to be made. Table 5-1 illustrates how capacity varies with location of feed point and/or belt speed.

5.1 PRIMARY SYSTEM - CONVEYORS

Table 5-2 shows how each conveyor system meets the transport requirement. No single flight system can handle the full 10 kilometre length.

For the first three kilometre length, only the steel cord belt has the capacity to cope with 2400 tph over the 725 metre lift. The cable belt conveyor is limited to 1900 tph by the maximum size of cable which can be used (57 mm). The booster drives are not likely to be suitable because they would probably have to occupy the whole length of the drive to be able to transfer the power. Conveyor technology is at its limit at this tonnage on this leg.

For the second longer but less steep leg, capacity, gradient and length, are all well within the capabilities of each of the three conveyor systems. The steel cord belt drive unit would have to be placed underground with the consequent large excavation and heat dissipation problem. The same problem would arise with the cable belt conveyor, except that, for a small increase

TABLE 5-1

Variation of Belt Capacity with Loading Point Location - Selby Mine

Distance from Surface	Loading Point (Bunker)	Belt speed (m/sec)	Capacity (tph)
A STEEL CORD CONVEYOR			
4889 m	(B1)	2.5	725
7453 m	(B2)	3.94	1225
7654 m	(B3)	5.90	1825
7968 m		5.90	1850
8180 m		5.90	1875
8392 m		5.90	1925
8604 m		5.90	1950
8816 m		5.90	2000
9028 m		5.90	2025
9240 m		5.90	2050
9452 m		5.90	2100
9664 m		5.90	2125
9876 m		5.90	2125
9910 m	(B4)	5.90	2525
10010 m	(B5)	8.40	2525
12253 m	(B6)	8.40	2650
12383 m	(B7)	8.40	2025
14528 m	(B8)	8.40	2250
14628 m	(B9)	8.40	2075
14798 m	(B10)	8.40	1950
14909 m	(B11)	8.40	1800
B CABLE BELT			
4889 m	(B1)	7.62	4420
7654 m	(B3)	7.62	3212
10010 m	(B5)	7.62	2483
12383 m	(B7)	7.62	2136
14909 m	(B11)	7.62	1830

TABLE 5-2

Comparison of Conveyor Capabilities

	Cable Belt	Steel Cord Belt	Booster Drives
1. Single Flight 10,000 m, 900 m lift, 45° direction change, 2,400 tph	Cannot do as single flight even though can negotiate change of direction.	1. Cannot do as single flight with direction change (curves unacceptable). 2. Single flight with no direction change would require approximately 10,400 kW.	1. Cannot do as single flight with direction change (curves not acceptable). 2. Single flight with no direction change would require approximately 9,000 kW.
2. Multiple Flight - First Leg 3,000 m, 725 m lift, 2,400 tph	Maximum capacity of single flight conveyor for this leg is 1,900 tph governed by rope limits (57 mm diameter).	Single drive head at surface, using 1,800 mm belt at 3.8 m/sec requires approximately 6,700 kW power. Belt Factor of Safety = 6.2:1 with ST7000 steel cord belt.	Drive unit at surface (1,200 kW) plus four booster drives (1,200 kW) with belt at 3.8 m/sec at width of 1,400 mm. Factor of safety at 9:1 for type 15 belt.
	Alternatives 1. 9,600 tonne bunker at change of direction to absorb difference between second leg belt at 2,400 tph and first leg at 1,900 tph. First leg belt runs 6 hours longer to convey total output. Approximate power 4,600 kW at 4.3 m/sec speed for 1,300 mm belt.		Alternative Use steel cord belting at 1,400 mm, 3.8 metres/sec with drive head at 2,400 kW and two booster drives at 2,200 kW. Factor of safety 6:1 with ST4000 steel cord belt. (1) Required booster length may exceed available conveyor length.

TABLE 5-2 (Cont'd)

	Cable Belt	Steel Cord Belt	Booster Drives
2. Multiple Flight - First Leg (Cont'd)	Alternatives (Cont'd) 2. Twin cable belts, side by side at 1,200 tph, 4.3 m/sec, 950 mm belt. Approximate power 3,050 kW. This option would be approximately 20% more expensive (capital cost) than Alternative 1.		
- Second Leg 7,000 m, 175 m lift, 2,400 tph	(a) Drive unit placed underground at change of direction, 1,300 mm belt at 4.3 metres/sec requires 2,450 kW power.	(a) Drive unit underground, 1,400 mm belt at 3.8 metres/sec required 3,900 kW with safety factor of 7:1.	Drive unit underground 1,400 mm belt at 3.8 metres/sec with drive unit and two booster drives totalling 3,600 kW (say each approximately 1,200 kW) using type 12 but with a 9:1 safety factor.
	(b) Drive unit placed on surface and cables run above conveyor in first leg. Power requirement 2,750 kW with about 8% increase in capital cost of conveyor.	(b) Drive unit underground, 1,800 mm belt at 2.54 metres per second requires 3,700 kW with safety factor of 6:1.	

in capital cost (8%) the drive unit could be located on the surface and the drive cables run down the first leg at roof level.

5.2 PRIMARY SYSTEMS - SLURRY PUMPING

This system can theoretically meet all the requirements by using multiple pumps including several booster pumps in each pipeline, and by using several parallel pipeline systems.

However, this has not been done in practice for these tonnages, lifts and distances and would thus represent a considerable step forward in the application of present technology.

In addition, the slurry pumping system is not suitable for a mine which is continually getting deeper, since the slurry pumping station, which is a large and complex plant, has to remain at the lowest point of the mine.

In the final analysis, therefore, slurry pumping systems cannot be considered as a viable system for the underground mines that are advancing deeper.

5.3 SECONDARY SYSTEMS

Compatibility with the primary system is the most important requirement after the preliminary criteria have been satisfied. This limits the suitable systems to belt conveyors.

Secondary systems have to meet a further criteria, that of being able to shorten or lengthen easily and quickly as the production face retreats or advances. Neither the cable belt nor the steel cord belt can realistically meet this requirement.

The most suitable secondary transport system is therefore the conventional fabric belt conveyor.

5.4 MAXIMUM PERFORMANCES - PRIMARY SYSTEM

.1 First Leg

Based on carrying coal over a distance of 3000 metres through a vertical lift of 725 metres; the limiting performances of the various belt types are:

	Cable Belt	Steel Cord	Booster Drives
Belt width (mm)	1300	1800	1400
Belt speed (m/sec)	4.3	3.8	3.8
Belt type	Cable Belt	ST7000	15
Safety factor (belt)	-	6.0	9.0
Max. power (kW)	4600	6700	*
Capacity (tph)	1900	2600	*

* Limit set by number of booster drives it is practical and economical to install. At these power levels it may not be possible to install four booster drives in the roadway length. Insufficient data is available to determine the critical lengths and powers.

.2 Second Leg

Based on carrying coal over a distance of 7,000 metres through a vertical lift of 175 metres, the limiting performances of the various belt types are:

	Cable Belt	Steel Cord	Booster Devices
Belt width (mm)	1800	1400	1400
Belt speed (m/sec)	4.3	4.3	4.3
Belt type	Cable Belt	ST7000	15
Safety factor (belt)	-	7.0	10.0
Max. power (kW)	4600	4800	6000*
Capacity (tph)	3900	3000	3800*

* Assuming booster conveyors occupy all the available length (maximum of four booster drives).

From these figures, it can seem that the requirement of 2400 tph on this leg is well within the capabilities of the systems although it is unlikely that the booster drive system would be operated with the full length of the main conveyor boosted.

3.5 MAXIMUM PERFORMANCE - SECONDARY SYSTEM

.1 PVC Solid Woven Belt

(a) Using the highest grade of PVC solid woven fabric belt currently available, the type 15 with a minimum warp strength of 2687 kg/cm, the maximum performances for the secondary belt conveyors handling coal at 600 tph are listed below.

1. Belt of 1050 mm width running at 1.8 metres per second
2. Maximum power transmitted 380 kW at 10:1 safety factor
3. Maximum horizontal distance at zero grade is 4464 metres
4. Maximum vertical lift over 2000 m length is 130 metres or a gradient of 6.5%

(b) A stronger PVC belt, type 20 with a minimum warp strength of 3582 kg/cm will shortly be available. This would raise the above figures to:

1. Maximum power at 10:1 safety factor 500 kW
2. Maximum horizontal length at zero grade 5950 metres
3. Maximum vertical lift over 2000 metres length 190 metres (9.5%)

(c) If the new Kevlar 49 Belt is used which has a minimum warp strength of 4000 kg/cm, and retaining the same 10:1 safety factor because of low joint efficiencies, the limiting factors become:

1. Maximum power 560 kW
2. Maximum horizontal distance 6640 metres
3. Maximum vertical lift 230 m (11.5%)

5.6 SYSTEM SELECTION

Table 5-3 lists the main characteristics for each of the three conveyor systems. Many of these comparisons are broad and subjective and can only be made objective when the systems are designed for a specific installation.

It is therefore not practical to try and evaluate the three systems more precisely to arrive at the most suitable system.

However, on the basis of the data provided in the report, it does appear that the choice of conveyor for each leg is limited to:

(a) First Leg (2400 tph)

1. Steel Cord Belt Conveyor
2. If the capacity is reduced to 1900 tph then the cable belt conveyor becomes a candidate

TABLE 5-3

Conveyor Data Comparison
(in Relation to Scope Conditions)

Item	Cable Belt	Steel Cord Belt	Booster Drives
Technology	Well Proven	Well Proven	Well Proven
Application	World Wide	World Wide	World Wide
Capital Cost Index	1.20	1.35	1.00
Operating Cost Index	1.00	1.04	1.06
Belting	Special	Special	Standard
Belting Cost Index	1.50	1.60	1.00
Belt Life (yrs.)	10-12	7-8	2-3
Belt Safety Factors		7:1	10:1
Belt Tension	Low	High	Average
Belt Weight	High	High	Average
Belt Elongation	0.4%	0.3%	3-4%
Belt Splicing	Complex	Complex	Simple
Joint Efficiency	90%	100%	70-80%
Drive Units	Single High HP	Single High HP	Multiple Lower HP
Drive Components	Massive Special	Massive Special	Average Standard
Structure	Special	Standard	Standard
Belt-Tension Arrangements	Complex	Simple	Simple
Starting	Simple	Simple	Complex
Control	Simple	Simple	Complex
Underground Drive Excavation	Extensive	Extensive	Minimal

TABLE 5-3 (Cont'd)

Item	Cable Belt	Steel Cord Belt	Booster Drives
Foundations (Including Drive House)	Complex	Complex	Complex
Ability to Extend Length	Fair	Complex	Good
Effect of Drive Failure	Shutdown	Shutdown	Reduced Capacity
Ability to turn coners in single flight	Yes, but complex	No	No
Heat Generation at Drive Heads	High	High	Low
Variable Speed	Easy	Easy	Difficult
Corrosion Resistance	Low	Medium	High
Power Cost Index	1.0	1.43	1.18
Availability (%)	99	99	92-98
Maintenance	Average	Minimal	Continuous

(b) Second Leg (2400 tph)

All three systems - cable belt, steel cord belt, fabric belt with booster drives - are applicable

6.0 CONCLUSIONS

This study has reviewed the various methods in use for transporting coal and waste underground. These included rope haulage, locomotive haulage, belt conveyors, the use of trackless vehicles, and hydraulic and pneumatic transportation systems.

The review examined the capabilities of each system for two requirements. First, for secondary haulage systems at 600 tph and second, for primary haulage systems at 2400 tph.

As a result of these reviews, we have reached the following conclusions.

6.1 PRIMARY TRANSPORTATION SYSTEMS

1. None of the systems reviewed is capable of handling, in a single flight, a tonnage of 2400 tph over a distance of ten kilometres through a vertical lift of 900 metres.

2. The following systems are not able to handle the tonnage requirement (2400 tph).

   - rope haulages in any form
   - compressed air and rack locomotive haulages
   - airlift and hydrohoist systems
   - pneumatic systems
   - trackless systems

3. The following systems cannot meet the distance requirement (10 km).

   - battery and compressed air locomotives
   - direct and main and tail rope haulages
   - airlifts and hydrohoists
   - pneumatic systems

4. The following systems cannot meet the gradient requirement (25%).

- locomotives
- trackless vehicles
- gravity slurry systems (positive gradient)

5. The only system capable of meeting the requirement to operate through a 45° bend, without a transfer station is the cable belt system through the use of an angle station. Angle stations are being developed for fabric belt conveyors, but, to date, are only available for the low powered drives (120 kW).

6. For the three km leg from the surface, the only practical system at 2400 tph is the steel cord conveyor. The maximum capacity of a cable belt for these conditions is 1900 tph. Booster conveyors are not practical since they would have to occupy almost the total length of the roadway.

7. The demands of the first leg at 2400 tph, 3000 m long, lift 725 m, are at the limits of present technology for belt conveyors.

8. The requirement for a capacity of 2400 tph represents an annual mine capacity well in excess of eight million tonnes per year. We believe that this is too high. A figure of 1800 tph would be more practical.

9. Slurry pumping systems are not suitable because they would require either pumps in series and parallel, or larger horsepower pumps than are currently in use. A leap forward in technology is required to meet the requirements.

10. For the second leg, any of the three belt conveyor systems are suitable. With the cable belt system, the drive could be put on the surface.

11. Surge capacity for the primary systems is best accommodated with mechanical, roadway or strata bunkers, located preferably at transfer points or at changes of direction.

12. When properly installed and maintained, conveyors offer excellent reliability.

13. Developments in monitoring and control ensure that conveyor systems are much safer, easier to automate and to operate from a remote control station on the mine surface.

14. Detailed comparison and ranking of systems must be related to site specific conditions, layouts, loading point locations, and feed rates. They cannot be developed in this study.

15. The use of curved conveyors may be of interest if mine layout permits, for coping with changes of direction of less than ninety degrees.

6.2 SECONDARY TRANSPORTATION SYSTEMS

1. The applicable systems are belt conveyors and hydraulic haulage.

2. The secondary transport system must be compatible with the primary system.

3. The steel cord and cable belt systems are not suitable because of overspecification and the need to keep altering the length of the conveyor.

4. Conventional fabric or kevlar solid woven conveyor belts are the most suitable system.

7.0 RECOMMENDATIONS

1. A determination should be made of the capacity in tonnes per hour for the primary system which can be accepted as being realistic.

2. A study should be made of the detailed characteristics of the three conveyor systems (cable belt, steel cord belt, and solid woven belt conveyors) related to specific mine layouts, gradients, tonnages, and feed rates and locations, to enable a realistic comparison to be made, and the most suitable system selected.

3. The potential for the use of curved conveyors and angle stations on high horsepower conveyors should be investigated.

4. The merits of the different forms of surge bunkerage (mechanical, roadway and strata) should be investigated.

RESUME DE LA DIRECTION

(Version Française)

1.0 INTRODUCTION

Le Laboratoire de la Recherche Houillère de CANMET à Sydney, Nouvelle Ecosse, a demandé l'établissement d'un rapport passant en revue l'information disponible concernant le transport du charbon et des déchets houillers provenant des mines souterraines et faisant un résumé de l'état actuel des systèmes pouvant être utilisés dans les mines souterraines de charbon.

Ce résumé doit traiter:

(1) des systèmes secondaires ayant une capacité de 350 à 600 tonnes par heure et pouvant fonctionner sur un pan incliné allant jusqu'à 25%,

(2) des systèmes primaires ayant une capacité de 1400 à 2400 tonnes par heure et pouvant fonctionner sur un pan incliné allant jusqu'à 25%,

(3) dans le cas des systèmes primaires, de la capacité de surcharge qui est trois fois le chargement maximum pour une durée de cinq minutes,

(4) de la dépendance, la disponibilité, la sécurité et l'adaptation au contrôle et à la manoeuvre à distance,

(5) des coûts d'installation, d'exploitation, d'entretien et de remplacement,

(6) du taux de rendement maximum.

L'étude des types de systèmes ainsi que le transport du personnel et des matériaux ont été volontairement exclus.

2.0 METHODES D'ETUDE

L'information a été recueillie au moyen:

(i) d'une recherche de documentation provenant des bases de données d'Amérique du Nord et de l'Europe et de la Bibliothèque des Mines du CISTI,

(ii) des demandes d'information adressées à des organisations étrangères,

(iii) des demandes d'information adressées aux fabricants de transporteurs, et

(iv) des données se trouvant sur place à Monenco.

La plus grosse partie des informations provient de la recherche de documentation (200 articles sur le sujet) et des fabricants de transporteurs.

Les renseignements les plus utiles ont été fournis par les fabricants de transporteurs tels que Cable Belt, Huwood, Dowty Meco, Anderson Strathclyde and Krupp, et les exploitants de mines utilisant les systèmes de pompes à schlamms tels que Consolidation Coal et Westar Mining.

3.0 LES SYSTEMES GENERAUX DE TRANSPORT

Les systèmes de transport du charbon et des déchets houillers actuellement utilisés dans les mines souterraines ont été examinés et six groupes identifiés:

(1) les systèmes de transport par câbles,
(2) les systèmes de transport par locomotives,
(3) les systèmes de transport sans rail,
(4) les systèmes de transport par bande,
(5) les systèmes de transport hydrauliques,
(6) les systèmes de transport pneumatique.

3.1 LE TRANSPORT PAR CABLES

C'est le type de transport du charbon qui est le plus ancien. Des câbles d'acier sont utilisés pour tirer des wagonnets ou berlines sur des rails. Ce système est d'une capacité limitée et dépend, en particulier, de l'inclinaison. Les frais d'entretien sont élevés. Pour ceci, il n'est presque plus utilisé pour le transport du charbon excepté dans quelques mines anciennes. Par contre, il continue à être employé pour le transport du personnel et des matériaux.

3.2 LE TRANSPORT PAR LOCOMOTIVES

Les locomotives sont utilisées sur une voie ferrée et marchent au diesel, à batterie, à trolley, à batterie/trolley et à air comprimé.

Les locomotives à air comprimé ont une énergie et un champ limités et sont utilisées uniquement dans quelques mines d'Europe fortement sujettes aux gaz.

Pour les locomotives à batterie/trolley et à diesel, l'énergie motrice disponible va jusqu'à 300 kW et pour les locomotives à batterie jusqu'à 150 kW.

Les types de locomotives standards peuvent fonctionner en toute sécurité sur des pans inclinés de moins de deux degrés seulement (1:30), mais elles sont normalement utilisées de taçon économique sur des pans inclinés d'un degré maximum (1:60).

Les progrès récents suivants permettront bientôt aux locomotives de fonctionner sur des pans beaucoup inclinés:

(1) des roues adhérentes qui peuvent être utilisées sur un pan incliné allant jusqu'à trois degrés (1:19),

(2) des systèmes de rails emprisonnants les roues, et qui permettent à la locomotive d'avancer sur un pan incliné allant jusqu'à quatorze degrés (1:4),

(3) une transmission à crémaillère qui peut opérer sur un pan incliné allant jusqu'à 18 degrés (1:3).

Jusqu'à présent, aucune locomotive n'a une puissance suffisante pour transporter des chargements de charbon de façon économique lorsque le pan est très incliné.

La découverte la plus récente dans le transport du charbon par train en Europe est le "Super Train". Un train comprenant deux locomotives à trolley de 300 kW assemblées en permanence à trente wagonnets de mine de trente tonnes chacun et qui transportent 10 000 tonnes par jour sur quatre kilomètres.

En Europe, les locomotives sont supposées avoir des avantages supérieurs aux bandes de transport si la distance à parcourir dépasse quatre kilomètres. Aux Etats-Unis, la distance considérée est de sept kilomètres.

Les systèmes de locomotives actuellement employés dans la plupart des pays du monde sont, soit entièrement automatiques, soit sont dirigés à distance.

3.3 LE TRANSPORT PAR VEHICULES SANS RAIL

Ces véhicules à pneus de caoutchouc et direction libre sont de deux types. Ceux qui chargent, transportent et déchargent, et ceux qui transportent et déchargent seulement. Les premiers ont une capacité allant jusqu'à quinze tonnes mais pour des raisons de coût ne fonctionnent que sur de courtes distances (300 m.) alors que les seconds ont une capacité allant jusqu'à trente tonnes. Bien que ces derniers peuvent parcourir de plus grandes distances, ils n'atteignent pas une capacité élevée et rentable lors d'un transport continu.

3.4 LES TRANSPORTEURS A BANDE

Les trois systèmes de transmissions suivants peuvent maintenant transporter une production élevée sur un pan incliné:

(1) Les transmissions auxiliaires ou linéaires qui consistent d'un équipement standard. Elles sont situées à l'intérieur d'un transporteur et transmettent une énergie supplémentaire au transporteur principal au moyen de la friction des bandes de transport. Ces transmissions réduisent la tension des bandes et permettent de plus grosses capacités tout en nécessitant moins de critères de spécification et, de ce fait, la fabrication des bandes est meilleure marché.

(2) des transmissions simples à tambours de large diamètre ayant une puissance en chevaux élevée et possédant une bande armée de câbles d'acier afin de transmettre en toute sécurité les hautes tensions nécessaires. Les câbles d'acier sont enserrés dans la bande afin de la rendre plus solide, mais le coût est élevé.

(3) les transporteurs "Cable Belt" pour lesquels la bande de transport repose sur deux câbles d'acier distincts qui transmettent l'énergie motrice. Par conséquent, la bande n'a aucun effort de traction à faire et les critères de spécification sont moindres, bien qu'il faille une fabrication spéciale.

Les bandes de transport conventionnelles en toile à transmissions auxiliaires fonctionnent à l'aide d'unités motrices allant jusqu'à 560 kW. Ces dernières peuvent être au nombre de cinq par transporteur (2000 tph). Les plus gros transporteurs souterrains à câbles d'acier et ceux de "Cable Belt" viennent d'être installés dans la nouvelle mine de Selby, au Royaume Uni, dont la production est de dix millions de tonnes par an. Les caractéristiques principales sont:

	Longueur (km)	Montée (m.)	Capacité (tph)	Puissance (kW)
Câbles d'acier	15	990	1830	10100
"Cable Belt"	15	990	1830	8750

Les découvertes dans l'utilisation d'"aramides" pour la fabrication des bandes de toile conventionnelles permettent d'atteindre une résistance à la traction approchant celle des bandes à câbles d'acier. Une économie considérable de poids, de frais d'exploitation et d'installation, est obtenue. Ceci va répandre l'utilisation des transporteurs à bande.

Les systèmes de transporteurs à bande constitue un risque d'incendie en puissance. Cependant, l'emploi des bandes ignifuges et les progrés effectués pour diriger et contrôler en toute sécurité et dépendance les transporteurs, ont abouti à un accroissement de leur utilisation souterraine pour le transport du charbon et des déchets houillers.

3.5 LES SYSTEMES HYDRAULIQUES

Les systèmes qui utilisent l'eau comme moyen de transport appartiennent à quatre catégories:

(1) les systèmes basés sur la gravité et qui dépendent d'un pan incliné (d'un minimum de 4 degrés) pour transporter un mélange d'eau et de charbon dans des canaux ouverts recouverts de plastique. (Un pan de 7 degrés est nécessaire dans le cas de canaux recouverts d'acier).

(2) les systèmes de remontée par air pour lesquels l'air comprimé est injecté dans une conduite. Le mélange d'eau et de charbon en mouvement est alors forcé vers le haut.

(3) Les systèmes de remontée hydraulique où le charbon est chargé par fournée dans une conduite contenant un courant d'eau à forte pression.

(4) les systèmes de pompes à schlamms où la boue de charbon et d'eau passe directement dans les pompes.

Ces systèmes n'ont pas une utilisation très répandue. Cependant, l'U.R.S.S., le Japon et la Chine transportent plusieurs millions de tonnes de charbon par an de cette façon.

Le seul système qui puisse avoir un intérêt pour les mines souterraines est celui des pompes à schlamms. Celles-ci sont actuellement utilisées au Canada et aux Etats-Unis pour remonter 900 tph d'une profondeur de 300 mètres. En U.R.S.S., leur capacité dépasse 1000 tph pour une remontée de 400 mètres.

3.6 LES SYSTEMES PNEUMATIQUES

Ceci ont été généralement utilisés pour transporter les déchets houillers lors du remblayage de la mine. Des systèmes à haut volume d'air et à basse pression ont été récemment utilisés pour remonter le charbon par le puits de mine de façon à en accroître la capacité de production. Cependant, la capacité de ces systèmes est basse (400tph) et est limitée à une remontée verticale de 300 mètres.

4.0 SELECTION DES SYSTEMES PRELIMINAIRES

Les systèmes de transport secondaires et primaires doivent répondre à certains critères obligatoires. Pour les systèmes secondaires, ce sont: une capacité de 350 à 600 tonnes par heure, la possibilité de fonctionner sur un pan incliné de 25% et sur une distance de 200 mètres à 2000 mètres.

Pour le système primaire, les facteurs critiques sont: une capacité de 1400 à 2400 tph, un pan incliné de 25%, une distance allant jusqu'à 10 kilomètres et la possibilité de prendre des virages de 45 degrés (Fig. 4-1).

Les tableaux 4-1 et 4-2 indiquent la façon dont chaque système de transport répond à ces critères pour les systèmes secondaires et primaires respectivement. Tout système qui échoue à un critère ("Non") est automatiquement éliminé.

Une étude du tableau 4-1 montre que seuls les systèmes de transport à bande et ceux hydrauliques répondent aux critères, dans le cas des transporteurs secondaires.

De même, pour les systèmes primaires, le tableau 4-2 indique qu'une fois encore, seul le transporteur à bande et les systèmes hydrauliques conviennent.

La quatrième partie du rapport examine de façon plus détaillée ces deux systèmes.

TABLEAU 4-1

Critères de compétence des systèmes secondaires (obligatoires)

	Capacité (600 tph)	Pan incliné (25%)	Distance (max. 2 km)
Rail			
- Diesel	Oui	Non	Oui
- Batterie	Oui	Non	Oui
- Trolley	Oui	Non	Oui
- Batterie /trolley	Oui	Non	Oui
- Air comprimé	Oui	Non	Oui
- Traction à crémaillère	Oui	Non	Oui
Transport par câble			
- Direct	Non	Oui	Oui
- Continu	Non	Oui	Oui
- De tête et de queue	Non	Non	Oui
Transporteurs			
- à câbles d'acier	Oui	Oui	Oui
- "Cable Belt"	Oui	Oui	Oui
- à transmissions auxiliaires	Oui	Oui	Oui
- conventionnels	Oui	Oui	Oui
Hydrauliques			
- basé sur la gravité	Oui	Oui(-)/Non(+)	Oui
- à pompes à schlamms	Oui	Oui	Oui
- à remontée par air	Oui	Oui	Oui
- à remontée par eau	Oui	Oui	Oui
Pneumatique	Non	Oui	Oui
Véhicules sans rail	Oui	Non	Non

NOTE: (1) Doit être aussi compatible au système primaire.
(2) Un "Non" dans une seule catégorie élimine le système.

TABLEAU 4-2

Critères de compétence des systèmes primaires (obligatoires)

	Capacité (2400 tph)	Pan incliné (25%)	Distance (10 km)	Virage de 45°
Rail				
- Diesel	Oui	Non	Oui	Oui
- Batterie	Oui	Non	Non	Oui
- Trolley	Oui	Non	Oui	Oui
- Batterie/trolley	Oui	Non	Oui	Oui
- Air comprimé	Non	Non	Non	Oui
- Traction à crémaillère	Non	Non	Oui	Oui
Transport par câble				
- Direct	Non	Oui	Non	Oui
- Continu	Non	Oui	Oui	Oui
- De tête et de queue	Non	Oui	Non	Oui
Transporteurs				
- à câbles d'acier	Oui	Oui	Oui	Oui
- "Cable Belt"	Oui	Oui	Oui	Oui
- à transmissions auxiliaires	Oui	Oui	Oui	Oui
Hydrauliques				
- basé sur la gravité	Non	Oui(-)/Non(+)	Oui	Oui
- à pompes à schlamms	(Oui)	Oui	Oui	Oui
- à remontée par air	Non	Oui	Non	Oui
- à remontée par eau	Non	Oui	Non	Oui
Pneumatique	Non	Oui	Non	Oui
Véhicules sans rail	Non	Non	Oui	Oui

NOTE: Un "Non" dans une seule catégorie élimine le système.

5.0 ANALYSE DES SYSTEMES

Les deux problèmes suivants sont apparus lors de l'analyse de la compétence des systèmes choisis à être utilisés dans les mines souterraines et sous-marines:

(1) le taux maximum de tonnage spécifié pour cette étude (2400tph) est élevé, même par rapport aux niveaux atteints de nos jours par certaines mines (Selby 1850 tph, Lingan Phalen 1800 tph). Dans certaines conditions, ce niveau présente des problèmes de capacité et, indique, en outre, qu'un tel taux se situe aux limites actuelles de la technologie.

(2) Pour pouvoir faire une comparaison et une classification significatives de chacun des systèmes, plusieurs détails sont nécessaires portant sur chacun des chantiers spécifiques, la vitesse d'alimentation, l'emplacement, la distance, l'inclinaison du pan, et le plan d'exploitation. Le tableau 5-1 illustre la façon dont la capacité varie en fonction de l'emplacement du point d'alimentation et (ou) de la vitesse de la bande.

5.1 SYSTEMES PRIMAIRES - LES TRANSPORTEURS

Le tableau 5-2 montre comment chaque système de transport satisfait les exigences de transport. Aucun système ne peut parcourir la distance totale de dix kilomètres en une seule course.

Pour la première étape de trois kilomètres, seule la bande armée de câbles d'acier est capable de transporter 2400 tph avec une remontée de 725 mètres. Le transporteur "Cable Belt" est limité à 1900 tph car la grosseur maximum du câble qui peut être utilisée est de 57 mm. Les transmissions auxiliaires ne conviendraient probablement pas car pour parvenir à communiquer l'énergie motrice, il leur faudrait occuper toute la longueur du transporteur. La technologie atteint ses limites pour le tonnage de cette étape.

TABLEAU 5-1

Variation de la capacité de la bande selon l'emplacement des points de chargement la mine de Selby

Distance de la surface	Point de chargement (Soute)	Vitesse de la bande	Capacité (tph)
A TRANSPORTEUR A BANDE ARMEE DE CABLES D'ACIER			
4889 m.	(S1)	2,5	725
7453 m.	(S2)	3,94	1225
7654 m.	(S3)	5,90	1825
7968 m.		5,90	1850
8180 m.		5,90	1875
8392 m.		5,90	1925
8604 m.		5,90	1950
8816 m.		5,90	2000
9028 m.		5,90	2025
9240 m.		5,90	2050
9452 m.		5,90	2100
9664 m.		5,90	2125
9876 m.		5,90	2125
9910 m.	(S4)	5,90	2525
10010 m.	(S5)	8,40	2525
12253 m.	(S6)	8,40	2650
12383 m.	(S7)	8,40	2025
14528 m.	(S8)	8,40	2250
14628 m.	(S9)	8,40	2075
14798 m.	(S10)	8,40	1950
14909 m.	(S11)	8,40	1800
B TRANSPORTEUR "CABLE BELT"			
4889 m.	(S1)	7,62	4420
7654 m.	(S3)	7,62	3212
10010 m.	(S5)	7,62	2483
12383 m.	(S7)	7,62	2136
14909 m.	(S11)	7,62	1830

TABLEAU 5-2

Comparaison de la compétence des transporteurs

	"Cable Belt"	A Bande Armée de Câbles d'Acier	A Transmissions Auxiliaires
1. Une course unique 10 000 m., 900 m. de remontée, changement de direction de 45°, 2 400 tph	Ne parvient pas à effectuer une course unique bien que peut exécuter le changement de direction.	1. Ne parvient pas à effectuer une course unique ni le changement de direction (virages impossibles). 2. Une course unique sans changement de direction nécessiterait environ 10 400 kW.	1. Ne parvient pas à effectuer une course unique ni le changement de direction (virages impossibles). 2. Une course unique sans changement de direction nécessiterait environ 9 000 kW.
2. Plusieurs courses - Première étape 3 000 m., 725 m. de remontée, 2 400 tph	La capacité maximum transportable en une seule course pour cette étape est de 1 900 tph car la grosseur du câble est limitée à 57 mm de diamètre. Options Une soute à charbon de 9 600 tonnes placée au changement de direction absorberait la différence entre la bande de la seconde étape de 2 400 tph et la première étape de 1 900 tph. La bande de la première étape fonctionne 6 heures de plus pour transporter la production totale. L'énergie approximative est de 4 600 kW à une vitesse de 4,3 mm/sec. pour une bande de 1 300 mm de large.	Une seule transmission de tête en surface utilisant une bande de 1 800 mm de large à une vitesse de 3,8 m./sec. nécessite approximativement une énergie de 6 700 kW. Le facteur de sécurité de la bande: 6.2:1 avec une bande armée de câbles d'acier ST7000.	L'unité motrice (1 200 kW) en surface plus quatre transmissions auxiliaires (1 200 kW), une bande avançant à une vitesse de 3,8 m./sec d'une largeur de 1 400 mm. Le facteur de sécurité est de 9:1 pour la bande de type 15. (1) Option Utilisation d'une bande armée de câbles d'acier de 1 400 mm de large avançant à une vitesse de 3,8 m./sec. avec une transmission de tête de 2 400 kW et deux transmissions auxiliaires de 2 200 kW. Le facteur de sécurité est de 6:1 pour une bande armée de câbles d'acier ST4000. (1) (1) La longueur des transmissions auxiliaires risque de dépasser la longueur disponible pour le transporteur.

TABLEAU 5-2 (suite)

	"Cable Belt"	A Bande Armée de Câbles d'Acier	A Transmissions Auxiliaires
2. Plusieurs courses - Première étape (suite)	Options (Suite) 2. Deux transporteurs "Cable Belt" jumeaux, côte à côte de 1 200 tph avançants à une vitesse de 4,3 m./sec. largeur de la bande 950 mm. L'énergie approximative 3 050 kW. Cette option serait environ 20% plus chère (frais d'installation) que l'option 1.		
Deuxième étape 7 000 m., 175 m. de remontée, 2 400 tph	(a) L'unité motrice mise sous-sol au changement de direction, une bande de 1 300 mm de large avançant à une vitesse de 4,3 m./sec. nécessite une énergie de 2 450 kW. (b) L'unité motrice mise en surface et les câbles courant au-dessus du transporteur pour la première étape. L'énergie nécessaire est de 2 750 kW avec une augmentation des frais d'installation du transporteur de 8% environ.	(a) L'unité motrice sous-sol, une bande de 1 400 mm de large avançant à une vitesse de 3,8 m./sec. nécessite une énergie de 3 900 kW pour un facteur de sécurité de 7:1. (b) L'unité motrice sous-sol, une bande de 1 800 mm de large avançant à une vitesse de 2,54 m./sec. nécessite une énergie de 3 700 kW pour un facteur de sécurité de 6:1.	L'unité motrice sous-sol, une bande de 1 400 mm de large avançant à une vitesse de 3,8 m./sec. avec l'unité motrice et les deux transmissions auxiliaires faisant au total 3 600 kW (soit, chacune d'environ 1 200 kW) avec le type 12 mais un facteur de sécurité de 9:1.

En ce qui concerne la seconde étape, plus longue mais moins inclinée, les trois systèmes de transport sont capables de satisfaire les exigences de capacité, pan incliné et distance. L'unité motrice du transporteur à bande armée de câbles d'acier devrait être mise sous-sol, ce qui nécessiterait une large excavation et poserait des problèmes de dissipation de la chaleur. Le même problème se poserait pour le transporteur "Cable Belt", à part que, si les frais d'installation sont quelque peu augmentés (8%), l'unité motrice pourrait être placée en surface et les câbles de transmission courraient au niveau du plafond sur toute la distance de la première étape.

5.2 SYSTEMES PRIMAIRES - LES POMPES A SCHLAMMS

Théoriquement, ce système satisfait toutes les exigences. Il utilise des pompes multiples y compris plusieurs pompes auxiliaires dans chaque conduite et est constitué de plusieurs systèmes de conduites parallèles.

En pratique, cependant, ceci n'a pas été employé pour de tels tonnages, remontées et distances et, par conséquent, son application à la technologie actuelle représenterait un progrès considérable.

En outre, le système de pompes à schlamms ne convient pas pour une mine qui devient constamment plus profonde puisque la station de pompes à schlamms, qui est une usine grande et complexe, doit être située au point le plus bas de la mine.

Par conséquent, en dernière analyse, les systèmes de pompes à schlamms ne peuvent pas être considérés comme viables pour les mines souterraines et sous-marines.

5.3 LES SYSTEMES SECONDAIRES

Une fois que les critères préliminaires ont été satisfaits, il est absolument nécessaire que les systèmes secondaires soient compatibles aux systèmes primaires. Ceci limite les systèmes de transport qui peuvent convenir.

Les systèmes secondaires doivent répondre à un critère supplémentaire, celui de pouvoir être raccourci ou allonger facilement et rapidement selon que le front de taille recule ou avance. Ni le transporteur "Cable Belt", ni celui à bande armée de câbles d'acier ne peuvent satisfaire cette exigence de façon réaliste.

Par conséquent, le système de transport secondaire qui convient le mieux est le transporteur conventionnel à bande.

5.4 PERFORMANCES MAXIMUM - LES SYSTEMES PRIMAIRES

0.1 Première étape

Il s'agit de transporter le charbon sur une distance de 3 000 mètres avec une remontée verticale de 725 mètres. Les performances limites des divers types de bandes sont:

	Bande "Cable Belt"	Bande Armée de Câbles d'Acier	Transmissions Auxiliaires
Largeur de la bande (mm)	1300	1800	1400
Vitesse de la bande (m./sec.)	4,3	3,8	3,8
Type de bande	"Cable Belt"	ST7000	15
Facteur de sécurité (de la bande)	-	6.0	9.0
Energie maximum (kW)	4600	6700	*
Capacité (tph)	1900	2600	*

* Limite à cause du nombre de transmissions auxiliaires qui peuvent être installées économiquement. Pour de tels taux, il ne serait peut-être pas possible d'installer quatre transmissions auxiliaires sur la longueur de la galerie. Les données sont insuffisantes à déterminer les longueurs et les taux d'énergie critiques.

0.2 La seconde étape

Il s'agit de transporter le charbon sur une distance de 7 000 mètres avec une remontée verticale de 175 mètres. Les performances limites des divers types de bandes sont:

	Bande "Cable Belt"	Bande Armée de Câbles d'Acier	Transmissions Auxiliaires
Largeur de la bande (mm)	1800	1400	1400
Vitesse de la bande (m./sec.)	4,3	4,3	4,3
Type de bande	"Cable Belt"	ST7000	15
Facteur de sécurité (de la bande)	-	7.0	10.0
Energie maximum (kW)	4600	4800	6000*
Capacité	3900	3000	3800*

* En supposant que les transporteurs auxiliaires occupent toute la longueur disponible (quatre transmissions auxiliaires maximum).

D'après ces chiffres, il semble que, pour cette étape, tous les systèmes sont capables de transporter 2400 tph. Cependant, il est peu probable que le système à transmissions auxiliaires puisse fonctionner si celles-ci occupent toute la longueur du transporteur.

5.5 PERFORMANCE MAXIMUM - LES SYSTEMES SECONDAIRES

0.1 La bande tissée solide en PVC

(a) En utilisant une bande tissée solide en PVC d'une excellente qualité, le type 15, pour laquelle la résistance minimum du fil de chaîne est de 2687 kg/cm, les performances maximum de ces transporteurs secondaires à bande à charrier 600 tph de charbon sont les suivantes:

1. une bande de 1050 mm de largeur avançant à une vitesse de 1,8 mètres par seconde,
2. l'énergie maximum transmise de 380 kW avec un facteur de sécurité de 10:1,
3. la distance horizontale maximum au niveau zéro est de 4464 mètres,
4. la remontée verticale maximum sur une longueur de 2000 m. est 130 mètres, soit un pan incliné de 6,5%

(b) Une bande en PVC plus robuste, le type 20, pour laquelle la résistance minimum du fil de chaîne est de 3582 kg/cm, sera bientôt disponible sur le marché, ce qui augmenterait les chiffres précédents à:

1. énergie maximum pour un facteur de sécurité de 10:1, 500 kW,
2. distance horizontale maximum au niveau zéro, 5950 mètres,
3. remontée verticale maximum sur une longueur de 2000 m., 190 mètres (9,5%)

(c) Si la nouvelle bande Kevlar 49, qui a une résistance minimum du fil de chaîne de 4000 kg/cm, est utilisée, et que le facteur de sécurité reste le même, 10:1, à cause d'une baisse d'efficacité due aux raccords, les facteurs limites sont alors:

1. énergie maximum: 560 kW,
2. distance horizontale maximum: 6640 mètres,
3. remontée verticale maximum: 230 m. (11,5%).

5.6 CHOIX D'UN SYSTEME

Le tableau 5-3 donne la liste des caractéristiques principales pour chacun des trois systèmes de transport. La plupart de ces comparaisons sont générales et subjectives, elles ne peuvent devenir objectives que si chaque système est désigné pour une installation spécifique.

Par conséquent, cela ne vaut pas la peine d'essayer d'évaluer ces trois systèmes plus en détail pour aboutir à celui qui conviendrait le mieux.

Cependant, à partir des données de ce rapport, il semble que le choix d'un transporteur pour chaque étape se limite à:

(a) Première étape (2400 tph)

1. Le transporteur à bande armée de câbles d'acier,
2. Si la capacité est réduite à 1900 tph, le transporteur "Cable Belt" peut alors être considéré.

TABLEAU 5-3

Comparaison des données des transporteurs
(par rapport à l'étendue des conditions)

Nomenclature	"Cable Belt"	à bande armée de cables d'acier	à transmissions auxiliaires
Technologie	bien éprouvée	bien éprouvée	bien éprouvée
Application	le monde entier	le monde entier	le monde entier
Index des frais d'installation	1,20	1,35	1,00
Index des frais d'exploitation	1,00	1,04	1,06
Bande	spéciale	spéciale	standard
Index du coût de la bande	1,50	1,60	1,00
Durée de vie de la bande (années)	10-12	7-8	2-3
Facteurs de sécurité de la bande		7:1	10:1
Tension de la bande	basse	élevée	moyenne
Poids de la bande	élevé	élevé	moyen
Elongation de la bande	0,4%	0,3%	3-4%
Jointure de la bande	complexe	complexe	simple
Efficacité des joints	90%	100%	70-80%
Unités motrices	unique puissance en chevaux élevée	unique puissance en chevaux élevée	multiples puissance en chevaux basse
Organes de transmissions	massifs spéciaux	massifs spéciaux	moyens standards
Structure de support	spéciale	standard	standard
Méthode de tension de la bande	complexe	simple	simple

TABLEAU 5-3 (suite)

Nomenclature	"Cable Belt"	à bande armée de cables d'acier	à transmissions auxiliaires
Mise en marche	simple	simple	complexe
Système de commande	simple	simple	complexe
Excavation pour la transmission souterraine	étendue	étendue	minime
Fondations (y compris la chambre de transmission)	complexes	complexes	complexes
Possibilités d'extension	passables	complexes	bonnes
Effet d'une panne de transmission	arrêt complet	arrêt complet	fonctionnement à capacité réduite
Possibilité de passer des virages en une course unique	oui, mais complexe	Non	Non
Emanation de chaleur aux unités motrices de tête	élevée	élevée	basse
Variation de la vitesse	facile	facile	difficile
Résistance à la corrosion	basse	moyenne	élevée
Index des dépenses d'énergie	1,0	1,43	1,18
Disponibilité (%)	99	99	92-98
Entretien	moyen	minime	continu

(b) Seconde étape (2400 tph)

Les trois systèmes -"Cable Belt", à bande armée de câbles d'acier et conventionnels à bande et à transmissions auxiliaires - peuvent être considérés.

6.0 CONCLUSIONS

Cette étude a passé en revue les diverses méthodes utilisées pour transporter le charbon et les déchets houillers souterrains. Celles-ci comprennent le transport par câbles, par locomotives, par transporteurs à bande, par véhicules sans rail et les systèmes de transport hydrauliques et pneumatiques.

L'étude a aussi examiné la compétence de chaque système à satisfaire deux exigences, premièrement pour les systèmes de transport secondaires, de 600 tph, et deuxièmement pour les systèmes de transport primaires, de 2400 tph.

Nous en avons tiré les conclusions suivantes.

6.1 LES SYSTEMES DE TRANSPORT PRIMAIRES

1. Aucun des systèmes n'est capable de transporter en une seule course, un tonnage de 2400 tph sur une distance de dix kilomètres avec une remontée verticale de 900 mètres.

2. Les systèmes suivants ne peuvent pas transporter le tonnage exigé (2400 tph)

   - les transports par câbles quel que soit le type,
   - les locomotives à air comprimé et à crémaillère,
   - les systèmes de remontée par air et par eau,
   - les systèmes pneumatiques,
   - les systèmes sans rail.

3. Les systèmes suivants ne peuvent pas couvrir la distance exigée (10 km)
   - les locomotives à batterie et air comprimé,
   - les transports par câbles direct et de tête et de queue,
   - les systèmes de remontée par air et par eau,
   - les systèmes pneumatiques.

4. Les systèmes suivants ne peuvent pas satisfaire l'exigence du pan incliné (25%)
   - les locomotives,
   - les véhicules sans rail,
   - les systèmes basés sur la gravité (pan incliné important)

5. Le seul système capable de passer un virage de 45° sans avoir besoin d'une station de transfert est le système "Cable Belt" qui utilise une station d'angle. Des stations d'angle sont en construction pour les transporteurs conventionnels à bande mais ne sont jusqu'ici disponibles que pour des transmissions de basse énergie (120 kW).

6. Pour les trois kilomètres à partir de la surface, le seul système pratique pour 2400 tph est le transporteur à bande armée de câbles d'acier. La capacité maximum du transporteur "Cable Belt" dans ces conditions est de 1900 tph. Les transporteurs à transmissions auxiliaires ne sont pas pratiques car il leur faudrait occuper presque toute la longueur de la galerie.

7. Les demandes de la première étape - 2400 tph, 3000 m. de long, une remontée de 725 m. - sont aux limites de la technologie actuelle pour les transporteurs à bande.

8. L'exigence d'une capacité de 2400 tph représente une capacité de production annuelle bien au-dessus des huit millions de tonnes par an. Nous pensons qu'elle est trop élevée. Le chiffre de 1800 tph serait plus réalisable.

9. Les systèmes de pompes à schlamms ne conviennent pas parce qu'ils nécessiteraient, soit des pompes en série et parallèles, soit des pompes d'une puissance en chevaux plus élevée que celles qui sont actuellement utilisées. La technologie doit faire un bond en avant pour parvenir à répondre à de telles demandes.

10. Pour la seconde étape, les trois systèmes de transport à bande conviennent. Pour le système "Cable Belt", la transmission pourrait être mise en surface.

11. Les systèmes primaires peuvent accommoder la surchage de capacité en utilisant des soutes mécaniques, de galerie, de couches, situées de préférence aux points de transfert ou aux changements de direction.

12. Lorsque les transporteurs sont correctement installés et entretenus, ils sont tout-à-fait sûrs.

13. Les progrès effectués dans le contrôle et la manoeuvre des systèmes de transport les ont rendus plus sûrs et plus faciles à automatiser et à faire fonctionner à partir d'une station située à distance, à la surface de la mine.

14. Une comparaison et une classification détaillées des systèmes doivent être faites par rapport aux conditions spécifiques des chantiers, aux agencements, aux emplacements des points de chargement et aux vitesses d'alimentation. Ceci ne peut pas être analysé dans cette étude.

15. L'emploi des transporteurs courbes pour effectuer des changements de direction de moins de 90° peut être considéré si l'agencement de la mine le permet.

6.2 LES SYSTEMES DE TRANSPORT SECONDAIRES

1. Les systèmes applicables sont les transporteurs à bande et le transport hydraulique.

2. Le système de transport secondaire doit être compatible au système primaire.

3. Les systèmes à bande armée de câbles d'acier et les transporteurs "Cable Belt" ne conviennent pas parce qu'ils nécessiteraient trop de critères de spécification et qu'il faudrait constamment changer la longueur du transporteur.

4. Les bandes de transport conventionnelles ou les bandes kevlar sont celles qui conviennent le mieux.

7.0 RECOMMANDATIONS

1. Il faudrait déterminer une capacité en tonnes par heure pour le système primaire qui puisse être acceptée comme étant réaliste.

2. Il faudrait étudier les caractéristiques détaillées des trois systèmes de transport (le transporteur "Cable Belt", celui à bande armée de câbles d'acier, et ceux conventionnels à bande) par rapport aux agencements spécifiques des mines, aux pans inclinés, aux tonnages et aux vitesses d'alimentation et aux emplacements. Ceci permettrait de faire une comparaison réaliste et de choisir ensuite le système qui convient le mieux.

3. Il faudrait approfondir la possibilité d'utiliser des transporteurs courbes et des stations d'angle pour les transporteurs ayant une puissance en chevaux élevée.

4. Il faudrait examiner plus à fond les mérites des différents types de soutes de surcharge (mécaniques, de galerie, et de couches).

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PART 1

INTRODUCTION

PART 1 - INTRODUCTION

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1.0 INTRODUCTION

This study was authorized in September 1984 by the Canadian Department of Supply and Services on behalf of the Department of Energy, Mines & Resources, CANMET, Coal Research Laboratory, Sydney, N.S.

The authorization to proceed was based on a proposal from Monenco Consultants Limited, Calgary, dated 23 July 1984 in which the objectives and scope of work were defined as follows.

1.1 OBJECTIVES

The objective of this work is to review the substantial body of information relating to the transport of coal and waste from underground coal mines and provide a state-of-the-art summary.

1.2 SCOPE OF WORK

1. Summarize developed concepts, approaches, techniques and technologies which are being used as transport systems for coal and waste in underground coal mines. This summary should address:

   (a) Systems with unit capacities of 350 tonnes per hour to 600 tonnes per hour.

   (b) Main systems with capacities of 1750 tonnes per hour to 3000 tonnes per hour.[1]

   (c) Provisions for each system to accept short duration surcharge in output of 3 times the values given in (b).

   (d) Ability of the system to operate without closing down or interruption.

   (e) Transport systems to be used on grades of up to 25%.

   (f) Adaptability of systems to remote monitoring and control.

---

[1] The tonnages given in item 1(b) were subsequently lowered to 1400 and 2400 respectively to represent a more realistic main system capacity requirement.

(g) Safety devices and general safety assistance. Resistance of systems to fire hazards.

(h) Capital, operating, maintenance and replacement costs.

(i) System reliability.

2. Analysis of systems must be in sufficient detail to allow a technical judgment as to the maximum attainable level of performance of each system. A ranking matrix will be developed incorporating each system evaluated.

Systems design and the transportation of men and materials were specifically excluded from the review.

PART 2

STUDY METHODS

PART 2 - STUDY METHODS

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2.0 STUDY METHODS

Coal is mined from underground deposits in many countries of the world. However, the main producing countries are USA, USSR, China, U.K., W. Germany, France, Canada, S. Africa, Australia and India.

In order to review the methods used for the transportation of coal and waste in underground coal mines over such widespread locations around the world, three methods of sourcing data were identified. These were by (i) literature search, (ii) data requests to foreign organizations, and (iii) data from manufacturers.

2.1 LITERATURE SEARCH

A total of ten computer databases including three in Europe were accessed and a total of 191 papers were identified of which some 140 proved of value.

In addition, a search was made of the technical journals, including foreign mining journals held at the Library of the Canadian Institute for Scientific & Technological Information, which identified a further 60 relevant papers.

2.2 DATA FROM FOREIGN ORGANIZATIONS

This proved to be the least successful source of information. No response was received to requests from specific mines in the U.K. due to problems created by the miner's strike. Similarly the response from Western Europe was also minimal. Data on the use of slurry pipelines for the transport of coal was however made available by two operators, Consolidation Coal Co. U.S.A. and Westar Mining, B.C.

2.3 DATA FROM MANUFACTURERS

A total of 380 recognized suppliers of transportation equipment, covering rope haulage, locomotives, conveyors and slurry pipelines, were identified. Information was solicited by letter and approximately 37% responded. Some of the data supplied related to system components, but over 30 respondents provided relevant systems data. In particular the data provided by Cable

Belt (USA and UK), Anderson Strathclyde (UK), Dowty Meco (UK), Huwood (UK) and Krupp (FGR) proved most useful for the belt conveyor review.

PART 3

TRANSPORTATION SYSTEMS - GENERAL

PART 3 - TRANSPORT SYSTEMS - GENERAL

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3.1 INTRODUCTION

The transportation of coal, men, and materials has often taken a secondary place to coal face production in many mines, because of the primary emphasis on output and productivity. Frequently the transportation systems have not been sufficiently developed and are not capable of efficiently transporting all of the coal produced from modern mechanised coal faces. These and other considerations have led to renewed interest in the problems of underground transportation in coal mines. In this study, the emphasis is on transportation of coal and waste but because of the interrelationship of transportation systems some mention is made of men and materials transportation.

A great variety of systems have been used in the past to transport coal underground in mines. Many methods such as hand-tramming and horse drawn tubs, shaker conveyors and scraper chain conveyors (over long distances) have thankfully long disappeared.

Current coal transportation systems can be divided into six groups:

(1) Rope haulage systems;

(2) Locomotive systems;

(3) Trackless haulage systems;

(4) Conveyor belt systems;

(5) Hydraulic transport systems;

(6) Pneumatic transport systems.

A suitable coal clearance system can be defined as one which:

(a) provides continuous clearance from the point of production to the surface, with high levels of safety and reliability, and at the production rate required by the producing unit.

(b) caters for substantial variations in the production rate, especially over short duration production peaks.

(c) is economical in manpower and cost, and which is capable of remote control or automation.

Each system will be briefly described in the following sections.

3.2 ROPE HAULAGE

This is one of the oldest of current coal transport systems. It is relatively simple to operate, but is expensive to maintain and has low capacities when considered for coal haulage over long distances and gradients.

Rope haulages usually operate on railtrack systems by direct rope, endless rope or main and tail rope methods. In each of these, a single haulage winch incorporating a rope drum or drums is usually employed.

On steep gradients, the direct rope haulage is used. The mine cars or tubs are attached to the rope and travel down the gradient using gravity, controlled by the brakes on the haulage (Fig. 3-1). Loads coming up the gradient are hauled up by the winch. In some mines where coal was lowered down the gradient, the weight was used to haul the empty train up the hill. In large installations, this could lead to the use of regenerative braking.

On undulating roadways, or those where gravity could not be used, both endless and main and tail systems are used. For the endless system, the winch drum acts as a capstan which powers an endless loop of rope. The haulage rope extends between the haulage tracks to a return wheel at the end of the system, returning along the side of the roadway (Fig. 3-2). The mine cars or tubs carrying the coal are attached to the rope by clamps. The main and tail system uses two separate ropes attached to each end of the train, which is then hauled along the roadway in a similar manner to the endless rope system, but the haulage winch has two drums instead of one (Fig. 3-3).

The advantages and disadvantages of rope haulages are given in Table 3-1. Except for a few special low capacity applications or in older mines, rope haulage for coal transportation is now obsolete because of its high maintenance cost and limited capacity. Their main continued use is for the transport of men and materials.

3.3 LOCOMOTIVE HAULAGE

331 INTRODUCTION

Locomotive haulage systems running on floor mounted rails are used extensively in the underground coal mining industry as a primary method to transport coal, waste rock, men and materials. They are favoured in stable roadways that have gentle gradients and where adequate clearances can be guaranteed so that high speeds can be safely obtained.

Monorail mounted locomotive powered systems are only used for men and materials transport.

Many different prime movers are used to operate the systems. These usually include battery electric, trolley electric, trolley-battery combinations, diesel and compressed air.

The selection of a prime mover best suited to a particular situation is a decision which must be based on transportation requirements and roadway conditions, such as gradient, haulage distances, environmental conditions and regulations. Although speed is of great importance for the transportation of men, capacity and flexibility are the primary considerations for the transportation of coal, waste rock and materials. Roadway gradient, size and physical conditions influence not only the choice of prime mover but also the method by which tractive power is transmitted to the track to move the locomotive.

332 PRIME MOVERS

Brief outlines of each prime mover type are given below:

(i) Battery Electric

Power to drive the locomotive is obtained from large rechargeable batteries carried on board the locomotive (Fig. 3-4).

Because they are easier to maintain than diesels, battery locomotives are often preferred for operation in trunk roadways. However if they are worked with heavy train loads, particularly hauling up gradients the battery life becomes short and they can become uneconomical. A major problem that has yet to be overcome with all battery powered vehicles is the lack of a safe means to discharge a battery in the event of an accident and the dangers of electrical sparks igniting methane gas. This usually prevents the use of battery powered locomotives near coal faces.

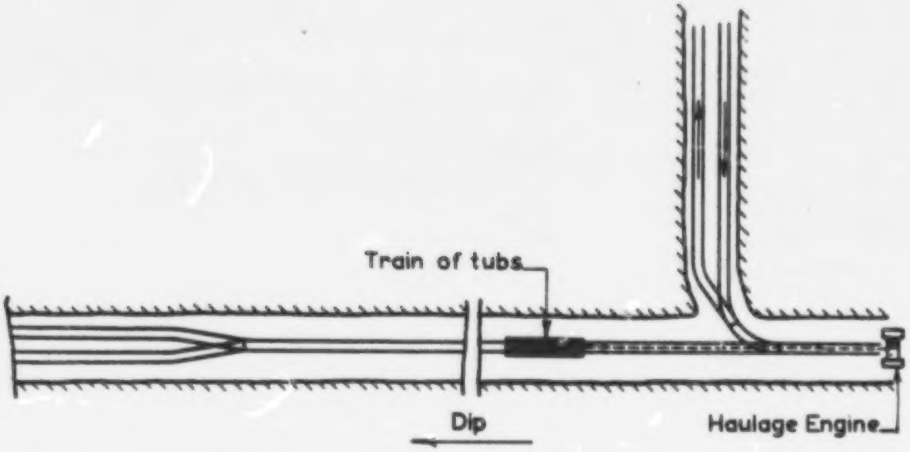


FIGURE 3-1 MAIN ROPE HAULAGE SYSTEM

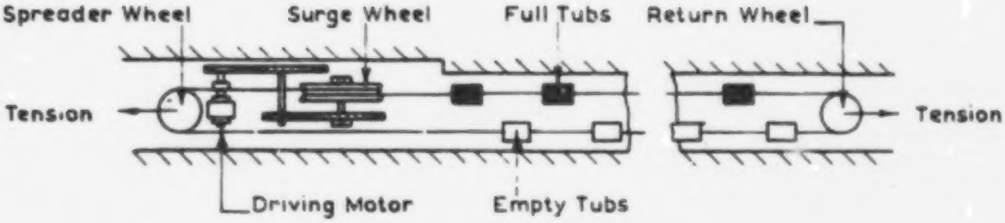


FIGURE 3-2(a) ENDLESS ROPE SYSTEM

FIGURE 3-2(b) ENDLESS ROPE HAULAGE

FIGURE 3-3 300HP ELECTRICALLY DRIVEN MAIN AND TAIL HAULAGE GEAR

TABLE 3-1

Conventional Rope Haulage Systems

	Direct Single or Double Drum	Endless	Main and Tail
Limiting Gradients	Minimum Gradients 1 in 10	Max Gradients 1 in 3	Max Gradients 1 in 10
Notes on limiting gradients	Steep consistent gradient required for the whole journey to allow for an adequate acceleration of train, due to gravity, at any point along the route	Theoretically no limiting gradient but in practice not normally installed where the gradient for the whole journey is in excess of approximately 1 in 3	Not normally installed where the average gradient exceeds 1 in 10
Additional Comments	Double drum haulages, with the drums fixed to the shaft, may be used successfully on steep gradients to haul two trains at the same time in opposite directions	Can be used where gradients are both in favour and against the load on the same journey	Usually installed in the roadways that have bends and undulate
Disadvantages	(1) Occupies more space than an endless (2) Rope pull varies with capacity at the drum	(1) Requires a rope tension device (2) Normally no rope storage capacity	(1) skilled operator (2) Occupies most space

... (Gont'd)

TABLE 3-1 (Cont'd)

Conventional Rope Haulage Systems

	Direct Single or Double Drum	Endless	Main and Tail
	(3) Rope coiling problem on the drum (4) Journey length limited by capacity of the drum (5) Needs a skilled operator	(3) Extra load is imparted to the rope due to tension device thus- (a) decreasing pay load or factor of safety (b) rope has greater tendency to lift at track undulations	(3) Usually more expensive (4) Rope pull varies with capacity of drum (5) Rope coiling problem on the drum (6) Journey length limited by capacity of the drums
Advantages	(1) Has rope storage capacity - can be extended easily (2) Does not require rope tension device (3) Rope lies better to the track through undulations	(1) Less skill required by operator (2) Occupies smaller space	(1) Has rope storage capacity (2) Does not require rope tension device (3) Tendency for rope to lift from the track at small undulations is controlled by operator

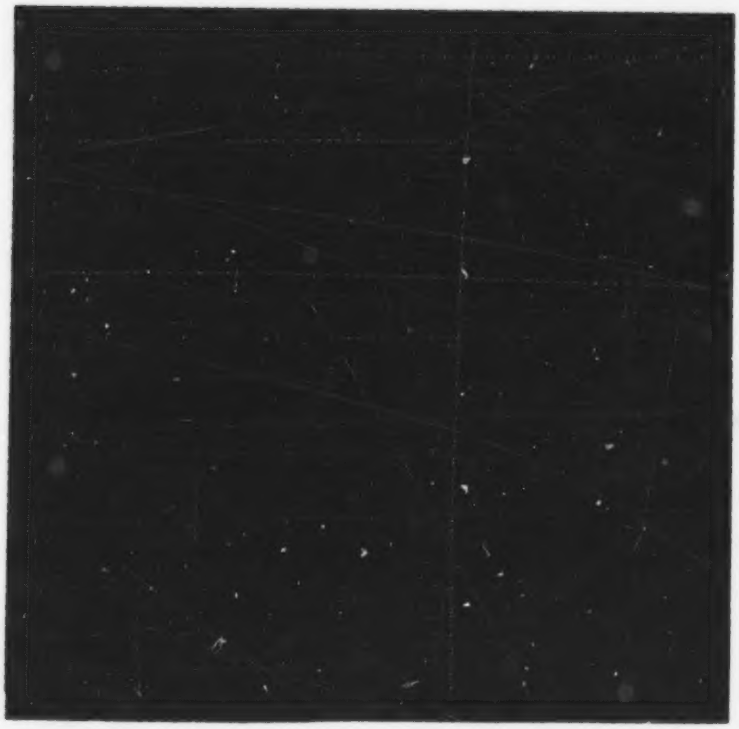


FIGURE 3-4 TYPICAL BATTERY LOCOMOTIVE

Recent developments in battery designs have led to considerable improvements in their ratios of energy to weight and volume. As even more powerful and reliable batteries are developed, the range of electric battery locomotives will possibly increase their popularity, particularly, if the sparking and battery discharge problems can be solved. Current research into flywheel energy storage devices may also enable the effective range or work capacity of battery locomotives to be increased.

Battery locomotives currently account for approximately 27% of all underground locomotives in use in the United Kingdom.

(ii) Trolley Electric

Trolley wire locomotives are widely accepted in the United States (USA) and in some European coal mines, but they are not fully accepted in the UK, however, for perceived safety reasons. Trolley wire locomotives, because of their high power to weight ratio, have distinct advantages in tractive effort and ability to negotiate gradients, and rapidly accelerate to higher speeds with significantly greater loads than battery locomotives and in some cases diesel locomotives.

Power is collected from an overhead wire or conductor, which is usually fully exposed and thus presents potential safety hazards particularly for the electrocution of personnel and from sparking at the contact between the collectors and the overhead wire (Fig. 3-5). These safety related problems are the primary reason that the British Mines Inspectorate has prohibited the use of overhead trolley wire locomotives within 275 m of a coal face and in return air. A further hazard associated with electric trolley locomotives is the danger of stray return electrical currents initiating a premature blast when explosives are being used in the general vicinity. Recent developments in protected and ventilated collectors for trolley locomotives show considerable potential for eliminating these hazards (Fig. 3-6).

(iii) Battery/Trolley

Combined function locomotives which operate from the trolley wire power source on main haulages, and from self contained batteries away from the trolley system, are greatly extending the flexibility and application of electric locomotives (Fig. 3-7). This is further enhanced by recent improvements which enable the battery to be recharged whilst the locomotive is operating from the trolley wire.

FIGURE 3-5 TROLLEY LOCOMOTIVE (POLE COLLECTOR)

(iv) Diesel

Diesel powered locomotives are the most popular type in use underground, having been first introduced underground in 1939 in the U.K. This popularity results from their great flexibility in both operating range and load capacity.

However the very nature of the power source presents environmental problems which impose some limitation on the use of diesel engines underground as they introduce both heat and toxic fumes into the mine air.

Regulations lay down stringent conditions for exhaust control through flame trap design and maintenance, exhaust gas dilution and regular sampling of the exhaust gases, with which the mine operator must comply.

Most diesel locomotives have direct mechanical drive to the wheels (Fig. 3-8), however, the introduction of hydraulic (oil) drives and bogie wheels has enabled a new generation of high speed locomotives to enter source in underground mines (Fig. 3-9). These locomotives are capable of reaching speeds of 50 kph compared with 32 kph for the standard locomotives.

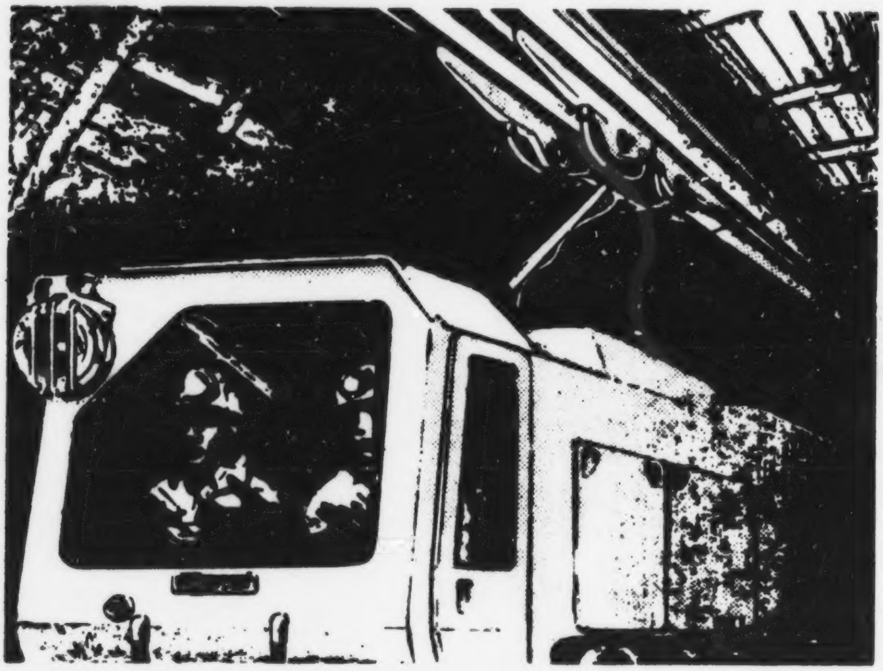
Aside from their potential environmental hazards, the main disadvantage of the diesel locomotive is that they need extensive skilled maintenance to ensure safe operation underground.

(v) Compressed Air

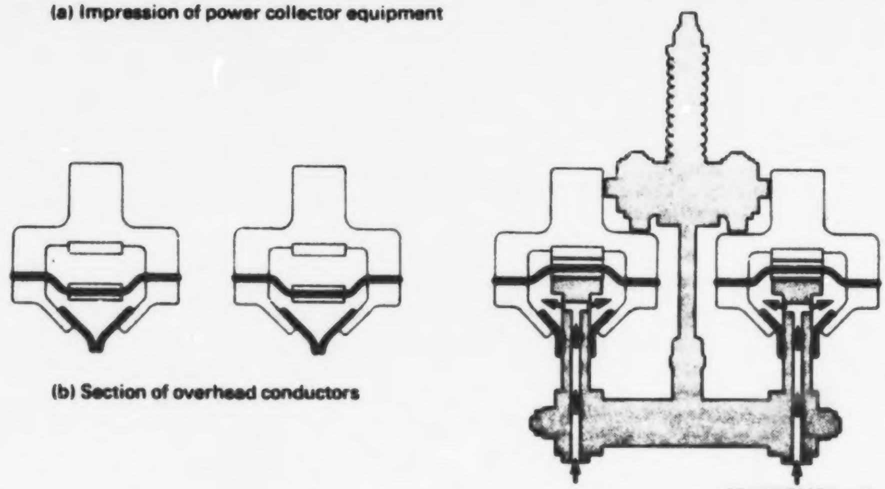
Compressed air prime movers (Fig. 3-10) were quite popular many years ago as they provided a safe power source that could be used in very gassy conditions. Unfortunately, they are very inefficient and have an extremely limited range of operation so are seldom used today. They are amongst the safest engines available for use in underground coal mines, having the advantages of being pollution free. They are still used in both the Ruhr and Belgium coalfields, where very gassy conditions exist. In these mines compressed air is in widespread use underground so that by regular recharging from a compressed air main, their operating range can be readily extended.

333 OPERATING CONDITIONS

Locomotives which depend for their drive on the friction between their steel driving wheels and the standard steel track are limited for reliable and safe operations to maximum gradients of 1 in 30 (2°). Most locomotive coal transport systems are limited to a



(a) Impression of power collector equipment



(b) Section of overhead conductors

(c) Section with collector in contact with conductors

FIGURE 3-6 PROPOSED PROTECTED OVERHEAD CONDUCTOR SYSTEM

FIGURE 3-7 TROLLEY BATTERY LOCOMOTIVE

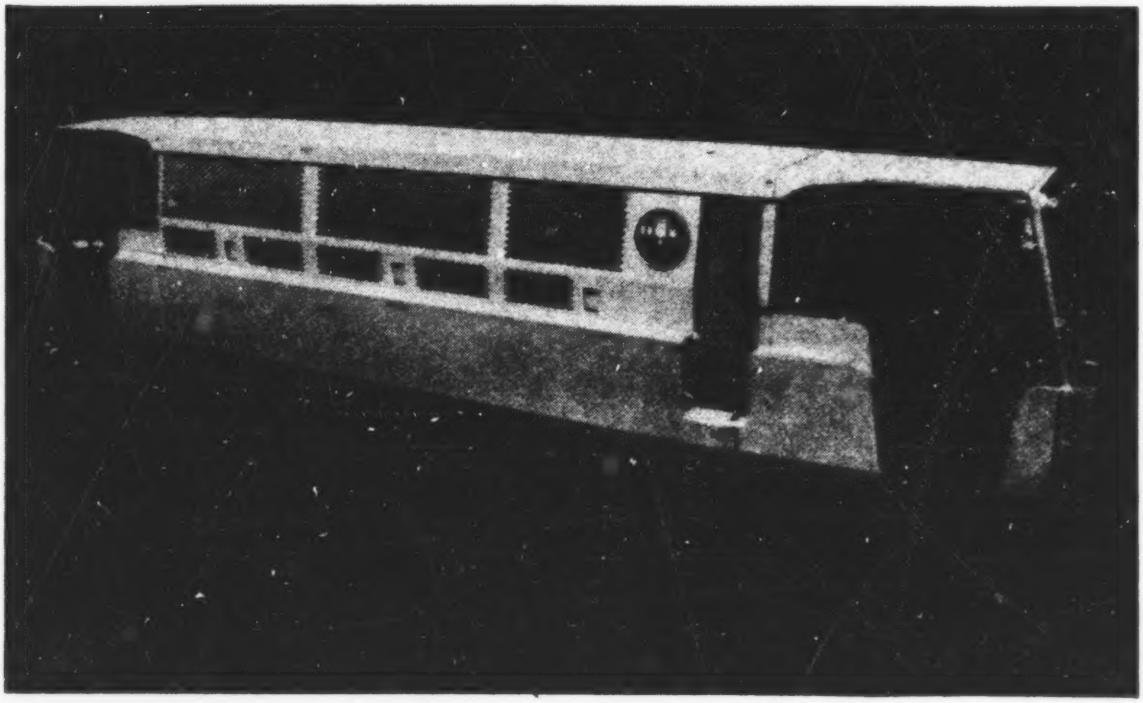


FIGURE 3-8 DIESEL LOCOMOTIVE

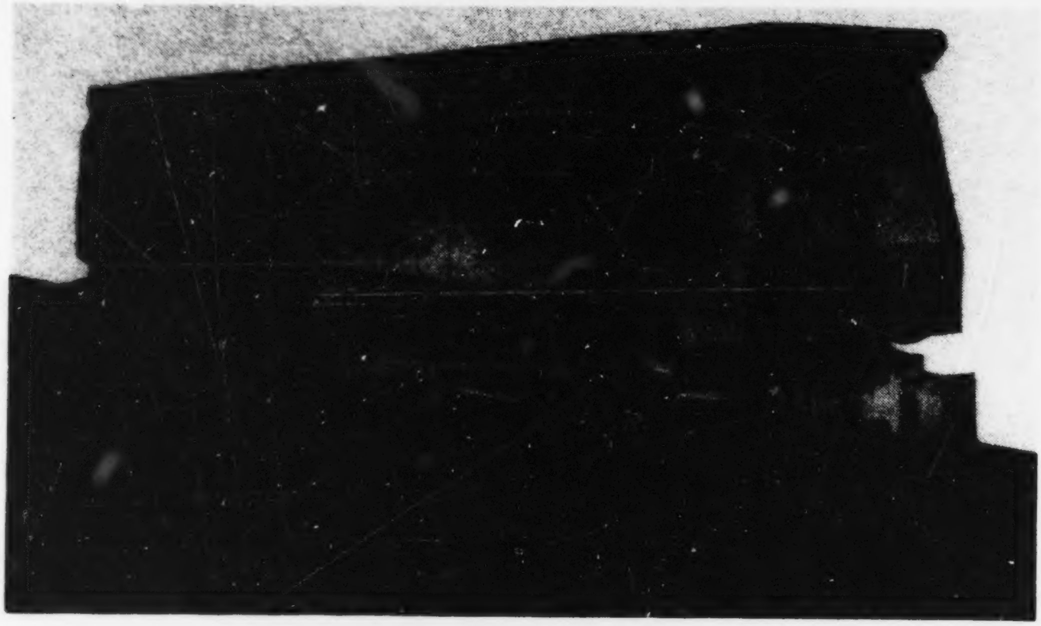


FIGURE 3-9 HIGH HORESPOWER (225kW) BO-BO DIESEL LOCOMOTIVE

FIGURE 3-10 COMPRESSED AIR LOCOMOTIVE

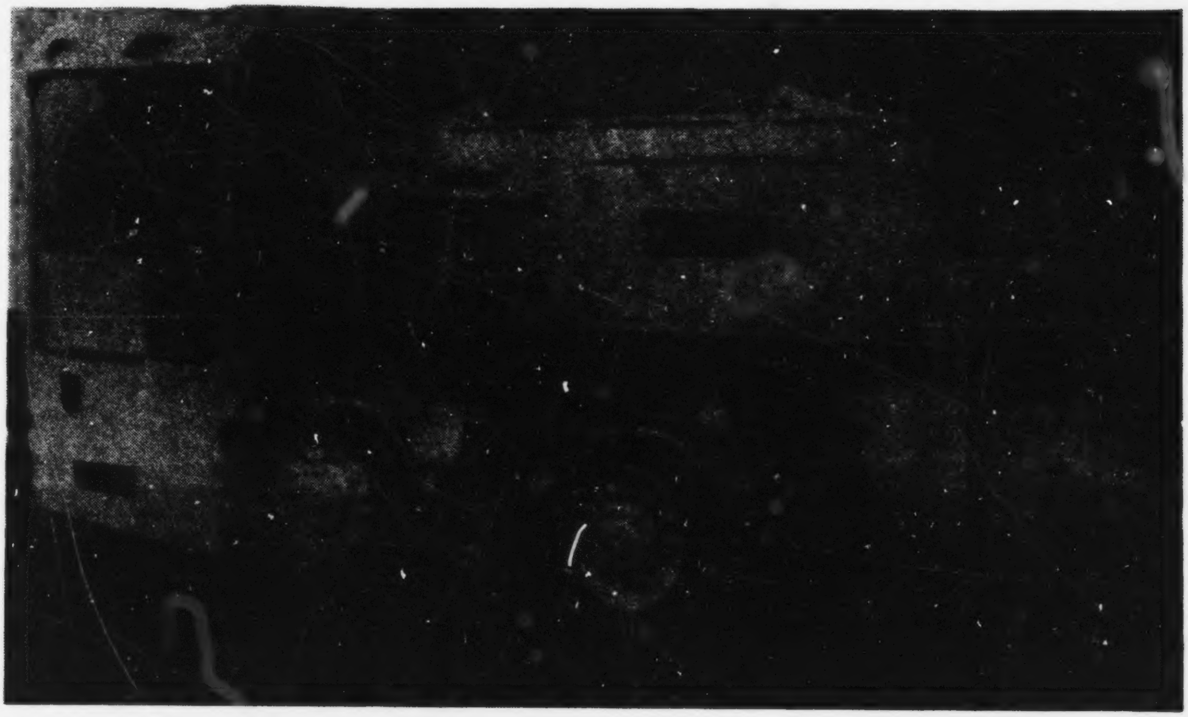


FIGURE 3-11 ADHESION BATTERY LOCOMOTIVE

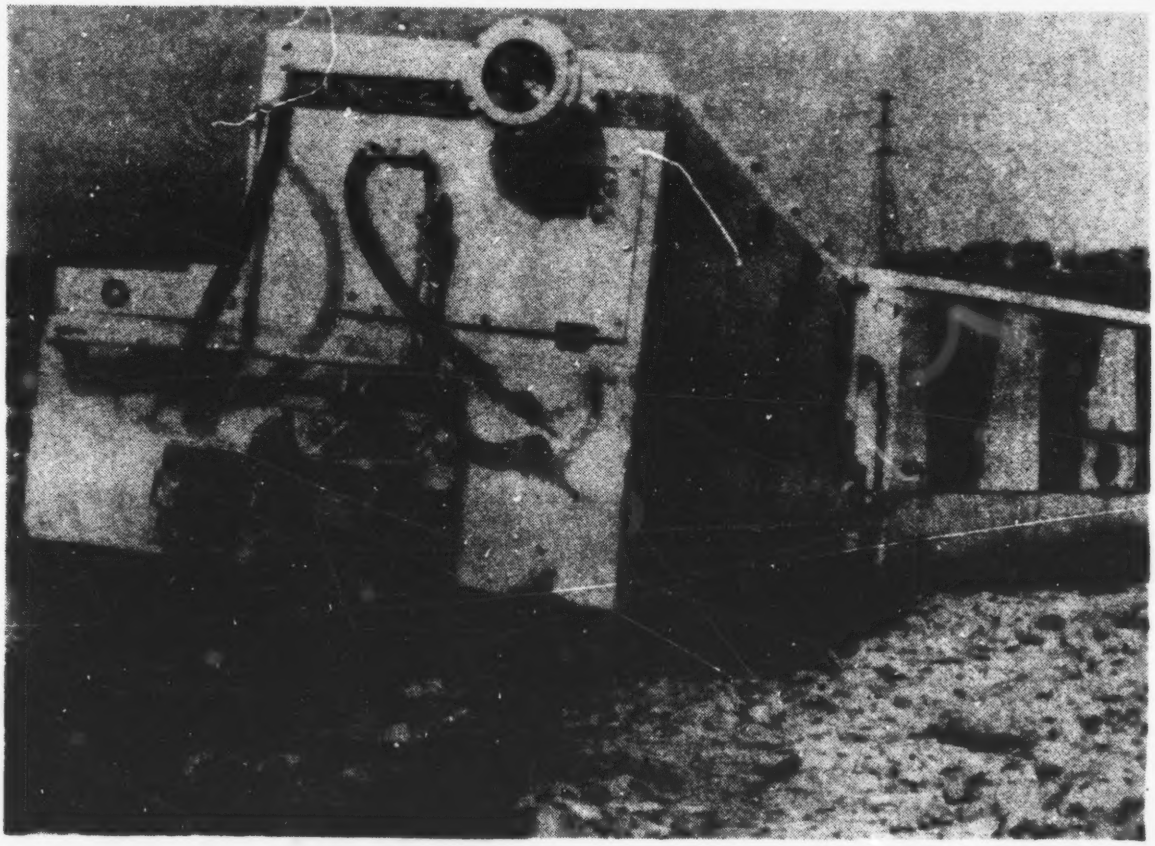
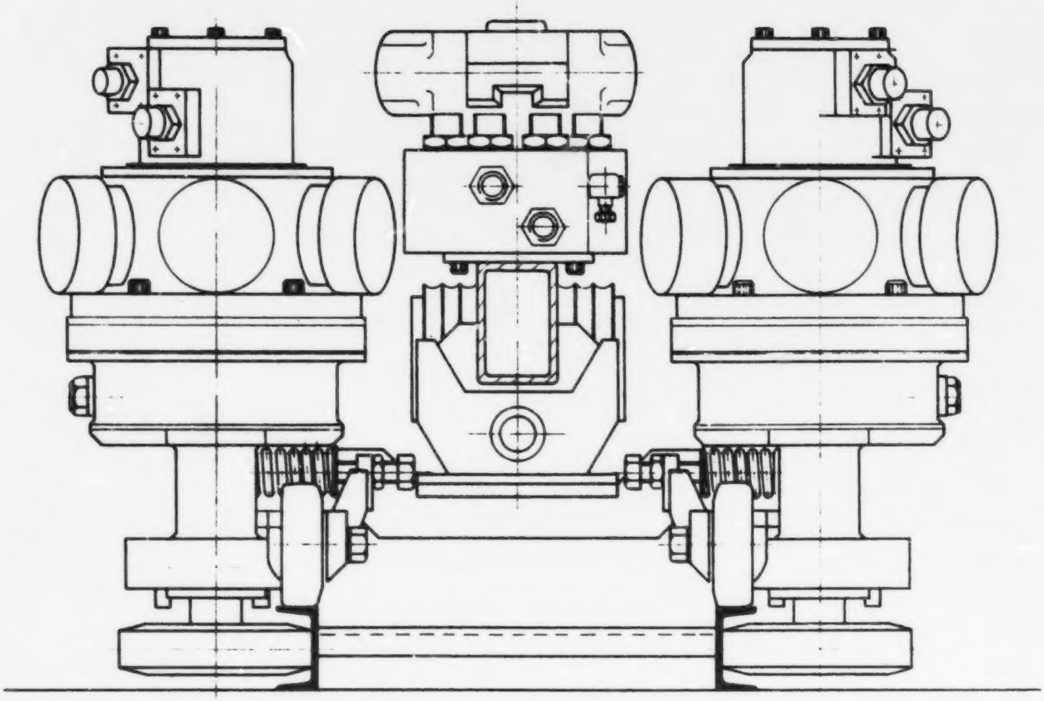


FIGURE 3-12 DIESEL LOCOMOTIVE WITH RACK DRIVE



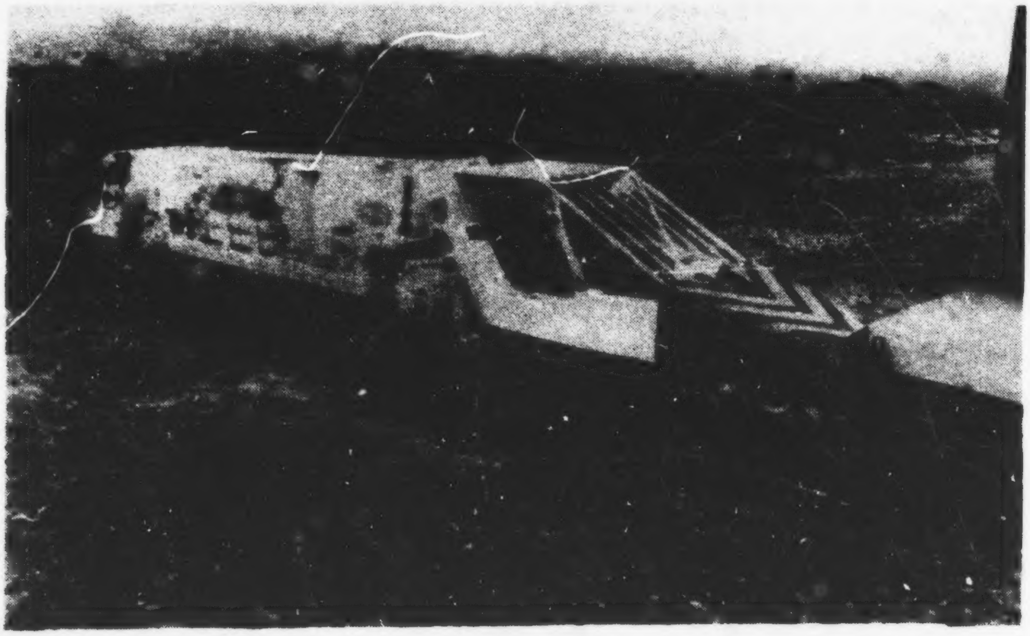


FIGURE 3-13 CAPTIVE RAIL LOCOMOTIVE

maximum of 1 in 60 (1°) in order that train capacities can be of an economical size.

However, although they have yet to be applied to coal transport, three new developments are being applied to improve the ability of locomotives to work on steeper gradients. These are rubber tired wheels, rack haulage, and the use of captive rail systems.

The addition of rubber tires to the locomotive wheels (Fig. 3-11) is permitting operations of locomotives on gradients up to 1 in 19 (3°), whereas the use of rack drive (Fig. 3-12) extends the operating range to 1 in 3 (18°). In this latter case, the drive is through a rack and pinion system, the driven pinion on the locomotive engaging with a rack between the tracks.

The captive rail system is the major development which has increased the performance of the diesel and battery electric locomotives. The improved adhesion is gained by using special polyurethane tires which are hydraulically squeezed onto the track with sufficient power to stop the wheels slipping but not enough to cause undue tire wear (Fig. 3-13). Diesel and electric powered locomotives using this method to transmit tractive effort to the rails can safely negotiate gradients up to 1 in 4 (14°).

The maximum power currently available from these 'steep seam' locomotives is 67 kW, although 110 kW units are under development. However not even these higher powered locomotives will be sufficient to provide economical locomotive operated transportation for coal on the steeper gradients of 1 in 4 (14°) required in this study.

The captive rail system is one method of ensuring that the locomotive and its train can follow sharper horizontal and vertical curves than the standard free rail system normally used. The rail is of a special shape, and the driving wheels or guide wheels trap the rail, thus preventing any possiblity of derailment and enabling better adhesion to be obtained.

The other system which offers similar advantages is the monorail track system, where the single rail is suspended from the roof of the roadway.

Monorails are most frequently used for the transportation of men and materials, however in some mines with low daily production rates they have been used to transport coal and waste rock. One such mine is an anthracite mine located in Pennsylvania, USA, where automatically dumping monorail cars are used to transport an average of 600 t of coal per 8 hour shift (Fig. 3-14).

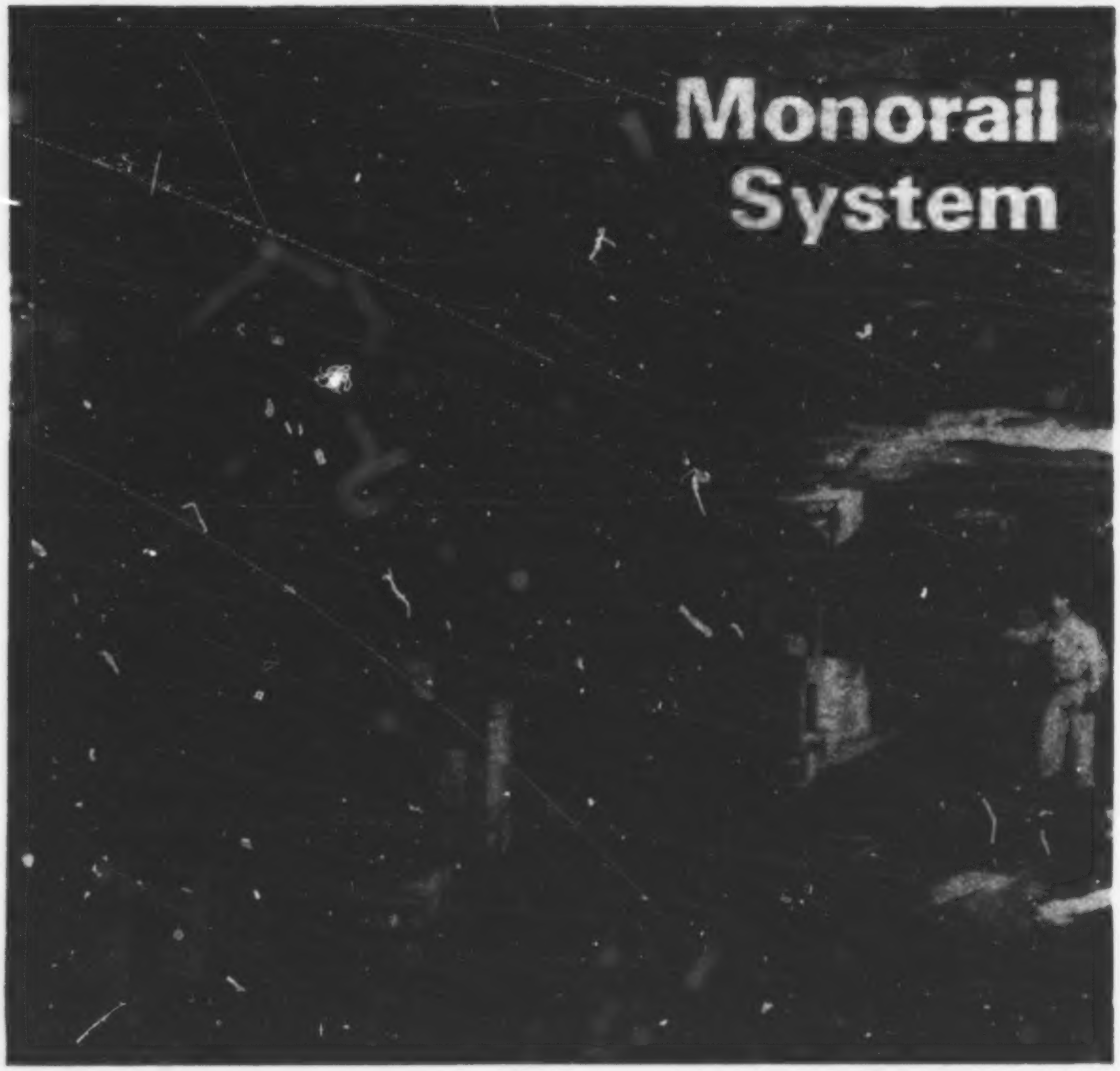


FIGURE 3-14 MONORAIL COAL HAULAGE

The locomotive reached its peak in terms of usage for coal transportation in the mid sixties from which time the developments in conveyor technology and safety have led to the rapid introduction of belt conveyors for coal clearance systems. This can be clearly seen in the UK where coal clearance is now handled by more than 5000 belt conveyors and only 300 locomotives. However, locomotives are, by far, the most common system used in underground mines for the transport of men and materials.

334 ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of locomotive haulage systems are summarized below:

The main advantages are:

1. they are flexible to operate
2. system capacity and/or length is not difficult or costly to vary
3. they have high speed capability
4. can be automated in many instances
5. they have an inbuilt capability to provide bunkerage
6. they can be used to transport men, materials and supplies as well as coal and waste rock
7. can negotiate significant horizontal changes in direction with ease

The main disadvantages are:

1. cannot operate effectively and at high production levels on gradients greater than one degree;
2. coal transportation is somewhat cyclical unless other systems such as bunkers or spare rolling stock can be used to provide storage;
3. require substantial sized roadways;
4. require stable strata conditions;
5. to attain high capacity must have dual track or passing places to allow separate trains to travel in different directions at the same time.

Although restricted by the track layout, locomotives have considerable flexibility in the type and nature of load drawn in the train. For example, personnel can be transported at either end of a shift by the same locomotive that transports materials, coal or waste rock during the shift.

335 TRANSPORTATION SYSTEMS AND CAPACITIES

The typical rail haulage system for coal, powered by locomotives, comprises one or more loading stations inbye the mine, usually double track, or single track with controlled passing places, and a discharge station at the shaft or surface drift bottom. The capacity of the system is determined by the size of mine car, (usually one to ten tonnes), the length of haul, the power of the locomotives and the number of trains in operation.

The capacity of the haulage system can often be increased by installing additional locomotives and rolling stock as required. It is also relatively inexpensive to extend the haulage distance, as a large percentage of a locomotive system's capital cost is invested in the rolling stock. It has been claimed that the least expensive form of coal bunkerage, other than strata bunkers, is provided by mine car rolling stock. Additionally different qualities of coal, or coal and waste rock, can be transported to the shaft in separate cars or trains where they can be wound to the surface in discrete batches thus reducing the problems associated with product handling and separation in the coal preparation plant.

Typical of modern day locomotive systems are those used for coal transport in West Germany, where the horizon mining system requires long haulage distances over virtually level roads. At the General Blumenthal mine in the Ruhr, a twin track haulage road, 20 km long, is used by 25 locomotives to convey fully automatically and unmanned, up to 25,000 tonnes per day, with an average haulage distance of 15 km. All operations are controlled from a central station. Each train consists of 40 - 25 tonne bottom discharge mine cars which are hauled at up to 40 km/h by 300 kW trolley locomotives.

Prior to these developments, coal trains comprised a single 65 kW diesel locomotive hauling 40 - 3 tonne mine cars at an average speed of 10 km/hr. The length of the train was 140 metres for a total 120 tonnes payload.

Recent developments have led to the introduction of the long 'super' train. This is 350 metres in length and comprises 30 - 30 tonne mine cars hauled at 25 km/h by two 300 kW trolley locomotives (one at each end of the train). This system is automatic, with the aim being to have only one such train per mine. The use of such a system requires considerable bunkerage to enable the working faces to produce continuously whilst the train is away from the loading station.

Evaluations by Rukrkohle have shown that, in the specific conditions in Western Germany, for any mine with an output of 10,000 tonnes per day (saleable), the super train concept has a capital cost advantage over conveyor systems for distances of 4 km upwards, and an operating cost advantage for distances of 2.5 km upwards.

It is thus clear, that where the gradients are suitable (less than 2%) locomotive systems can be attractive for the longer haul high output situations.

Locomotive haulage systems can be readily automated, irrespective of the type of prime mover.

Remote control and automation has been successfully applied in many countries including USA, Sweden and W. Germany, particularly in metalliferous mines for the transportation of ore. For example, at Grangeburg in Sweden, a remotely controlled haulage system has been installed and six diesel-electric locomotive powered ore trains are operated from a central control room with all the loading and discharging functions monitored by closed circuit television and an electronic display provides instantaneous and constant location and situation information of all rail mounted objects. The trains are directed according to the level of ore in storage bunkers and the locomotives and all loading, transportation and discharging arrangements are either fully automated or remotely controlled.

At the General Blumenthal mine, FRG, a completely automatic driveless locomotive system has been operating successfully since 1967. Reports on this coal haulage installation, state that it has advantages over normal manned systems in cost, efficiency and safety. In the USA a detailed investigation has been carried out into the design of a totally automated rail haulage system using 50 tonne pantograph type electric locomotives each with its own on-board computer. As an example of the sophistication of the system the computer can even detect wheel slip and automatically initiate sanding whilst reducing power to the wheels. An infrared train presence detector is used in key areas, such as track intersections and an automatic derailment detector automatically switches on the emergency brakes when a derailment occurs. One of the largest and most advanced automatic underground train transportation systems in use today is located at the Henderson Mine where some twenty four, 50 tonne d.c. electric locomotives are used.

336 NON-CONVENTIONAL METHODS

A relatively new development taking place in France combines the rail and conveyor transport systems. Known as the "Rolling Corridor", it makes use of the linear motor and provides high capacity, high-speed transportation over short or long distances.

It utilizes linear induction motor propulsion requiring no mechanical linkages for power transmission. The linear motor is a synchronous motor with a short circuited rotor rolled out in a single plane. The motor sections are 1.5 m in length, shaped like U-troughs, and are joined to one another by flexible connections to form a continuous trough 225 m long (Fig. 3-15). This train of pans is propelled by driving stations placed at intervals less than the length of a train.

A typical system is 2.3 km long incorporating four trains. The speeds in the various sections of the system are:

loading	3.0 metres/sec
full speed loading	7.0 metres/sec
discharging	2.4 metres/sec
full speed empty	7.6 metres/sec

The round trip cycle time for the 69 tonnes train is 14 minutes giving a system capacity with four trains of 660 tonnes/hour.

The linear motor train system can be fully automated and operate in winding or undulating roadways and there is virtually no electrocution or fire hazard with the system.

3.4 TRACKLESS TRANSPORTATION

341 INTRODUCTION

Trackless or free steered vehicles are the generic names for rubber tired vehicles that do not operated on rail tracks, additionally they are then subdivided into vehicles that transport coal, men or materials. Load-Haul-Dump (LHD) is the term generally applied to all trackless vehicles used to load and transport coal and rock. LHDs are front end loaders or scoop trams in the true sense as they load coal and rock into a bucket or scoop mounted on the front of the vehicle and transport it to be dumped onto succeeding elements of the haulage system (Fig. 3-16). Shuttle cars, ram cars, tractor trailer units and trucks have no self loading capability

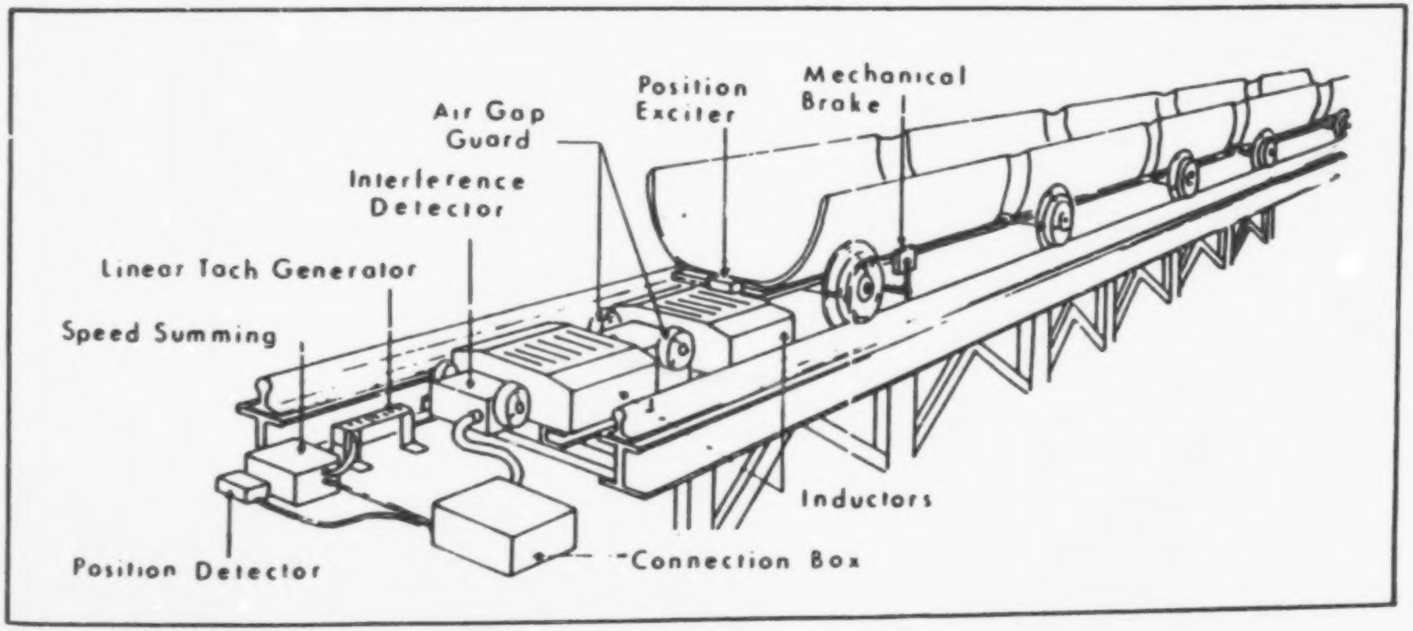
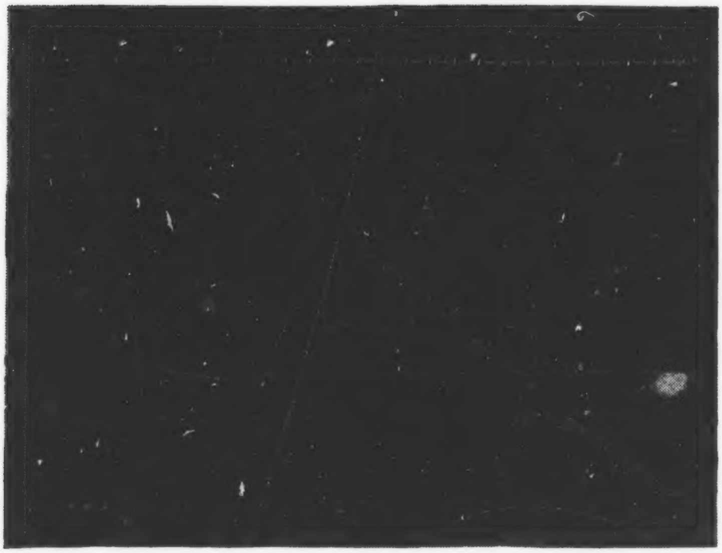


FIGURE 3-15 "ROLLING CORRIDOR" LINEAR MOTOR CONVEYOR TRAIN

(a) REMOTE CONTROLLED DIESEL

(b) CABLE REEL

FIGURE 3-16 LHD TRACKLESS VEHICLES



3-17(a) SHUTTLE CAR DIESEL POWERED

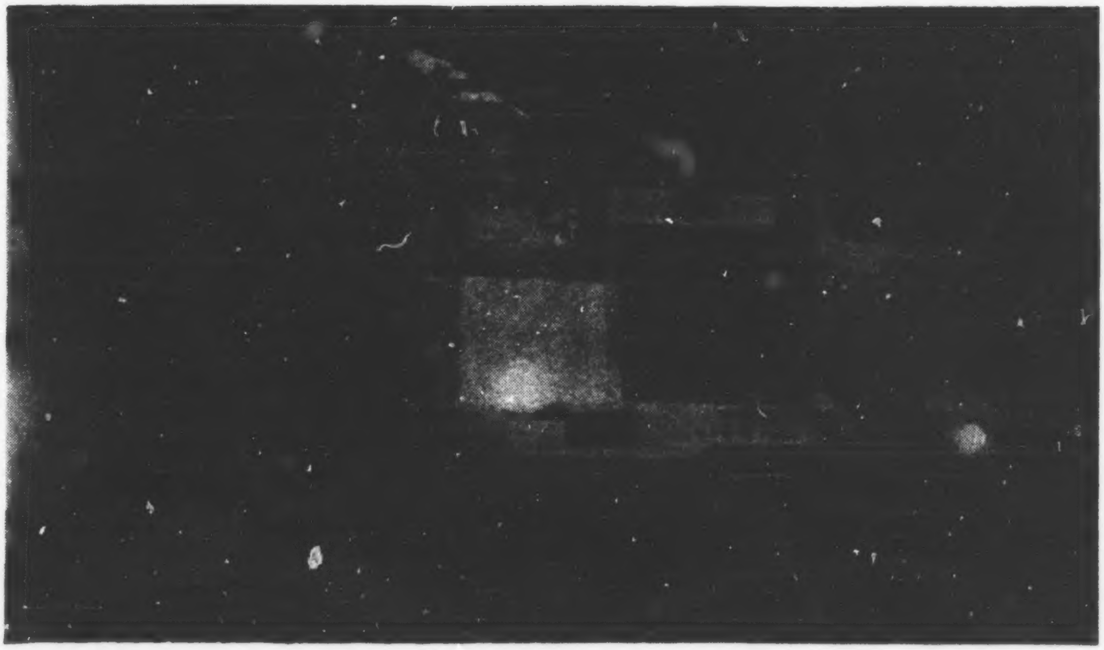


FIGURE 3-17(b) UNDERGROUND DUMP TRUCK

and are loaded by the coal cutting machine or some other means so are referred to as Haul-Dump (HD) equipment (Fig. 3-17). LHD equipment is also used to transport heavy materials and equipment, such as roof supports around the mine and as general purpose clean-up machines.

Locomotive and rope haulage systems can safely operate with quite small clearances, because they are held in place by rails. In contrast free steered vehicles, such as the LHD and HD, have no such restraints on their movements and therefore can only be used safely in roadways with adequate clearances and sound floors. When several trackless vehicles are used to serve a single underground coal production unit there must be carefully placed passing places in the roadways or an alternative return route from the face so the LHDs do not inadvertently collide. As multiple roadways are more normal in the room and pillar mining system, trackless vehicles are more common in this type of coal mining.

In the USA approximately 80% of underground coal production comes from room and pillar mines many of which are well suited to optimize the use of trackless vehicles. In these mines trackless vehicles are often used to transport coal from the advancing coal mining machines at the coal face to the intermediate or main haulage which could be a conveyor or rail system. Unfortunately, the use of free steered vehicles for face coal haulage although providing flexibility, has often introduced considerable non-productive time for the coal mining machines. Hence the development of continuous coal transportation systems to alleviate this problem (Fig. 3-18).

Because of the continuous high volume of coal production from a longwall face, trackless vehicles cannot compete with conveyor systems for coal transportation in longwall gate roadways. However there is considerable interest in the further development of trackless transportation for men and materials in longwall mines and also to provide more flexibility for coal and waste clearance in development headings.

In other mineral mines, particularly in potash in Germany, and in metal mines in USA, Canada and Scandinavia, LHD units are used as the collector haulage systems feeding onto locomotive or conveyor main haulage systems. These techniques are applied to room and pillar mining and various forms of stoping. Load capacities range from 1 cubic metre to 15 cubic metres, with haulage distances generally not exceeding 500 metres.

Shuttle cars and ram cars usually are limited to 10 tonnes capacity, with operating distances limited to 300 metres and often much less. If haulage trucks are used, capacities extend up to 30 tonnes, and haulage distances can be several kilometres since the trucks are operating as the main transport system.

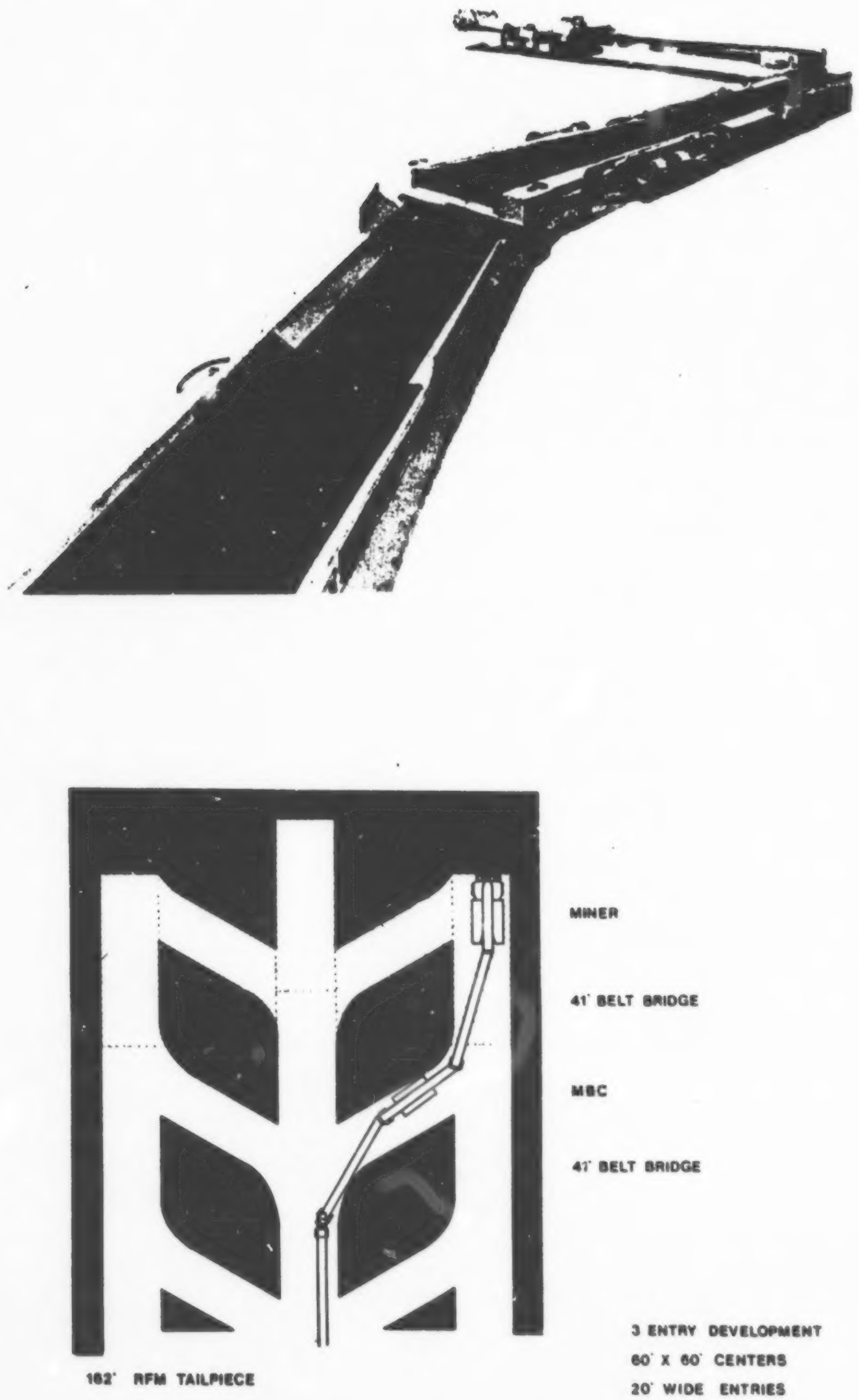


FIGURE 3-18 CONTINUOUS HAULAGE SYSTEM

342 DESIGN OF TRACKLESS VEHICLES

Prime movers for trackless vehicles can be the same as those used for locomotive transportation systems, with the addition of the cable reel shuttle car which is analogous to the trolley wire locomotive system as it operates from the mine's primary electricity supply (Fig. 3-19). The use of the trolley wire system is limited to haulage trucks, which use a pantograph whilst on the trolley system and a cable reel when operating away from the trolley wire (Fig. 3-20).

Currently, there are several hundred diesel powered trackless vehicles in use in underground coal mines in the USA and it is claimed that extended use of diesel powered LHD and HD vehicles could increase overall room and pillar mine's face productivity by up to 30 per cent and permit the complete elimination of conveyors in short panels.

Manufacturers have tried numerous methods to improve the manoeuverability of trackless vehicles by providing four wheel drive and steering. Articulation of the chassis between the front and rear wheels is a common feature of most modern LHD design and improves machine manoeuvrability and tracking. Unfortunately it does not prevent and sometimes aggravates the breakdown of weak floors nor allows the use of small 90 degree intersections.

343 ROADWAY FLOOR SURFACES

Sound roadway floors are the key to the successful operation of trackless vehicles in underground coal mines. Although trackless vehicles can be used on unsurfaced, uneven, soft and muddy floors these floors often present severe hazards, especially when the vehicles are operated at high speeds. To combat floor problems the French coal industry has developed an artificial surface consisting of gravel and ash bound together with a bituminous emulsion; when laid on a roadway floor and compacted with a vibratory roller, it gives an even and solid surface particularly in dry conditions. Where mine roadways are dry and have a short life a compacted mixture of water, gravel and ash can be used to form a temporary surface. Other trials include experiments with roadway surfacing using a special motor grader designed to level and compact natural floor material and the use of cement to stabilize existing floor material. Unfortunately all of these are costly and if required throughout the mine could economically preclude the use of trackless vehicles.

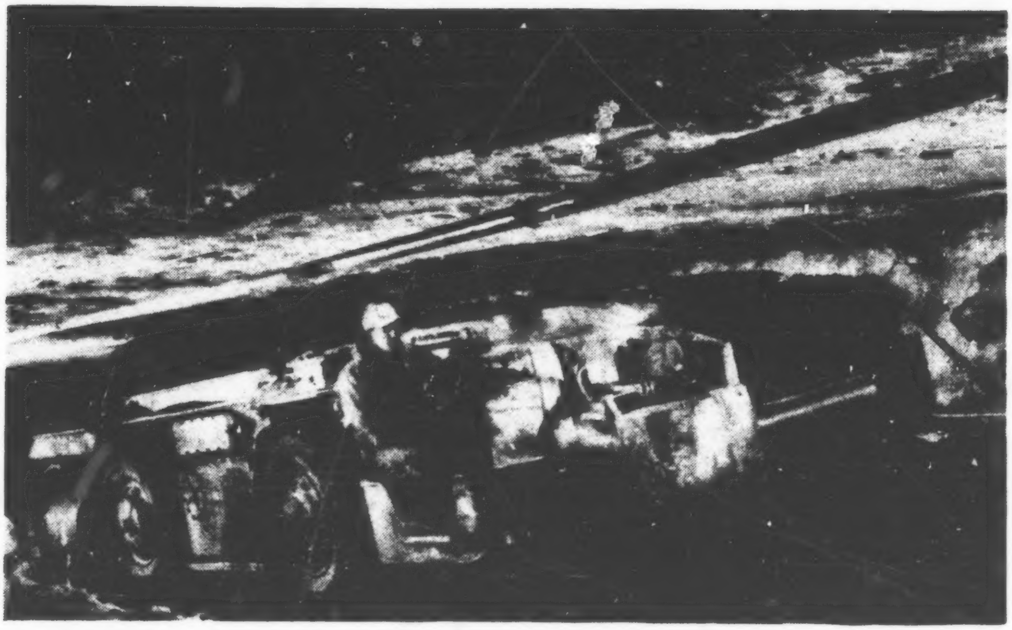


FIGURE 3-19 CABLE REEL SHUTTLE CAR A CARRING COAL ON A GRADIENT

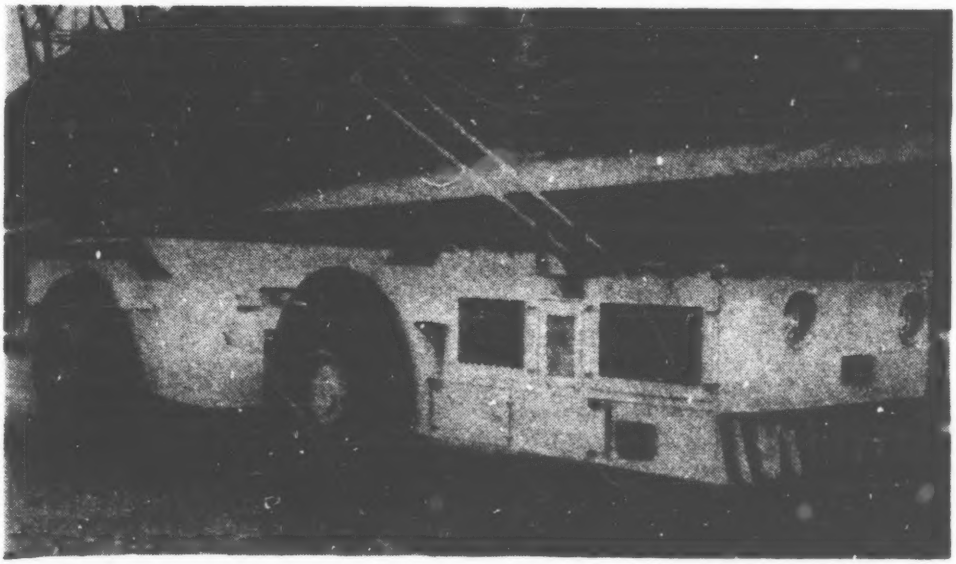


FIGURE 3-20 TROLLEY WIRE POWERED TRUCK

3.5 CONVEYOR TRANSPORTATION

351 INTRODUCTION

The mining industry is one of the world's largest users of conveyor transportation systems, the first conveyor being installed underground in 1906. Such systems are used extensively in underground coal mines for the transportation of coal and, to a lesser extent, waste rock and to a much lesser degree personnel, materials and supplies. In undergound coal mines using the longwall mining system, a series of belt conveyors is often used to transport coal directly from the coal face to the shaft for skip-winding, or in drift mines directly to the surface. Frequently these belt conveyor systems cover distances of many kilometres. With the trends in Europe, towards large, multi-mine complexes the dominance of conveyors for coal transportation, particularly, high capacity units, is increasing. In the UK 90% of all coal mined is transported by a conveyor system at least part of its way out of the mine. Continuity, reliability of operation, ease of automation, low personnel requirements and their lower height requirements when compared with other methods of coal transportation are considered the primary reasons for this popularity.

In room and pillar mines, particularly in the USA, conveyors are frequently used as the mainline coal transportation system with trackless, rubber tired vehicles transporting the coal from the continuous mining machines to a conveyor loading station. Although some estimates show that shuttle cars still handle up to 80% of all deep mined coal in the USA particularly in the immediate face area, there is considerable and growing interest in the development of continuous coal transportation systems which includes both conveyors and coal/water slurry transportation systems from the continuous miners at the coal face to the main transportation system.

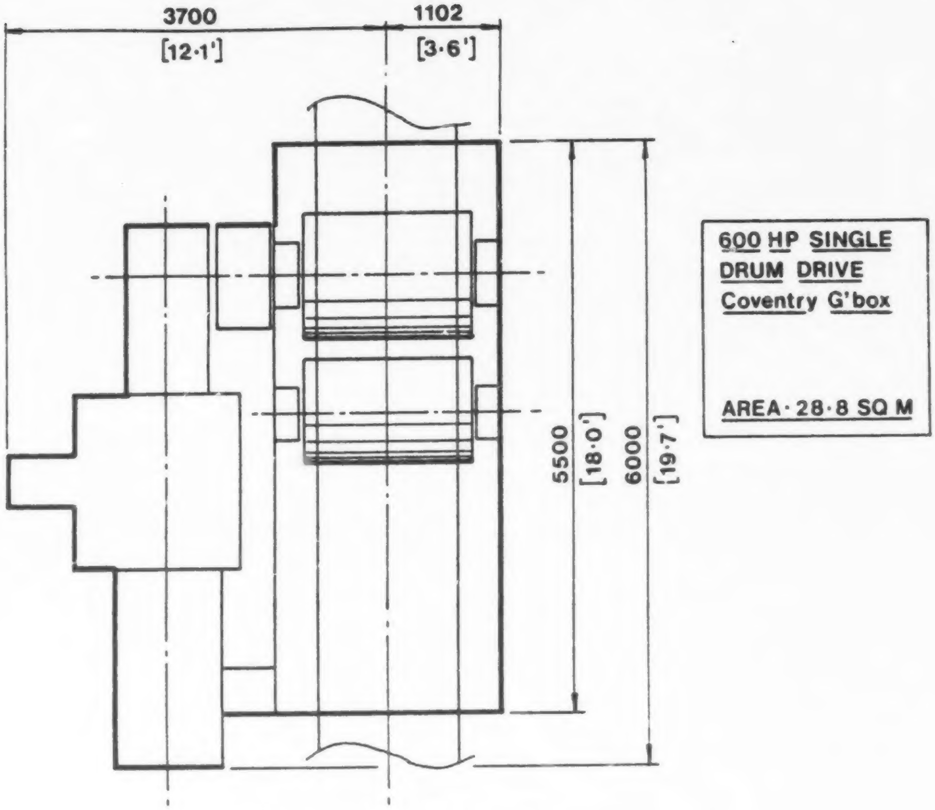
352 CONVENTIONAL CONVEYOR HAULAGE

.1 Conveyor Assemblies

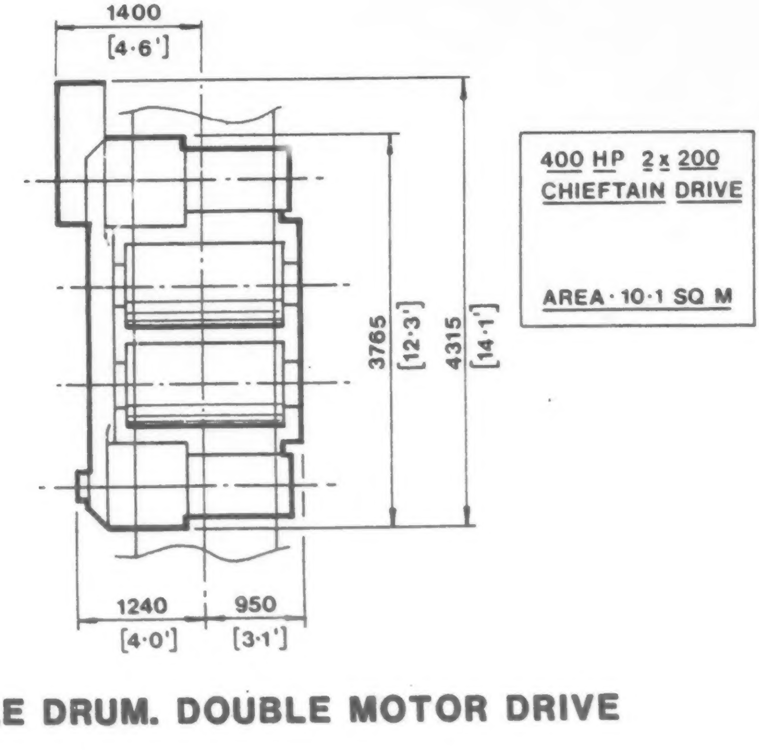
The conventional belt conveyor consists of five principal components, the drive unit, the support structure including the rollers, the belt, the belt tensioning equipment and the return receiving unit.

(a) Driveheads

The drive head on most conventional belt conveyors is a fixed unit comprising double steel driving drums, often

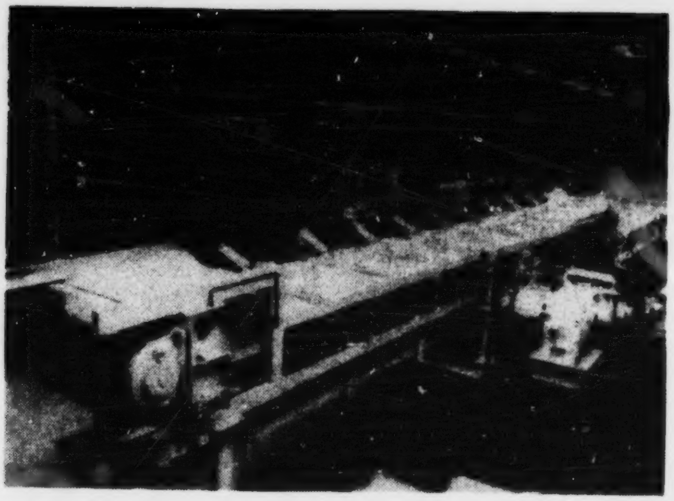


(a) SINGLE DRUM. SINGLE MOTOR DRIVE

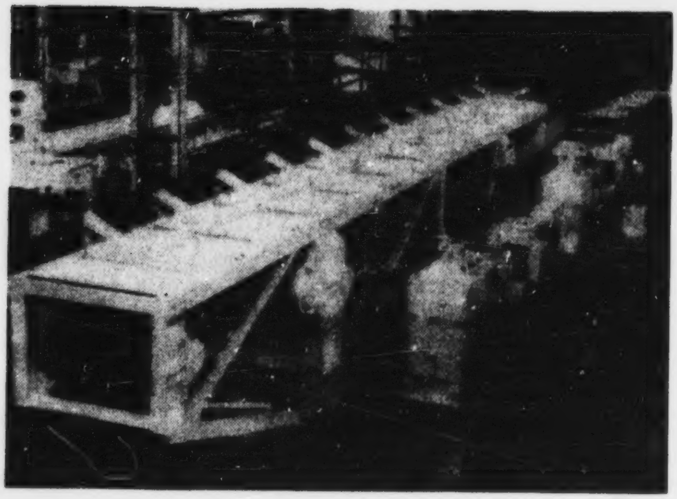


(b) DOUBLE DRUM. DOUBLE MOTOR DRIVE

FIGURE 3-21 TYPICAL CONVEYOR DRIVES



(a) SINGLE DRUM. SINGLE MOTOR



(b) DOUBLE DRUM. DOUBLE MOTOR

FIGURE 3-22 CONVEYOR DRIVES

lagged with friction material; powered by one or more electric motors through reduction gear boxes (Figs. 3-21 and 3-22). Underground belt drives of 300 - 450 kW are now widely used with belt speeds of up to 4.3 metres/second. These higher powers and speeds have enabled larger capacities to be handled in smaller spaces.

The fine control and smooth acceleration necessary for such powers and speeds is often obtained by the combination of squirrel cage motors and fluid couplings which control the torque transmitted over a wide range. These allow load sharing between multiple drive heads or multiple motors on one driveload, and by sequential starting of motors, reduce the aggregate value of current drawn.

(b) Structure

The supporting structure can consist of either rigid steel beams (Fig. 3-23) or flexible steel cables (Fig. 3-24), both of which can be mounted either on the floor or suspended by chains or ropes from the mine roof. Unfortunately, with both systems, the conveyor structure may move from its correct position if the roadway is deformed by strata pressures. The extent of work required to correct for misalignment caused by this movement is dependent on the type of conveyor used, being easier for the suspended type. On major installations laser beams are sometimes used to check for misalignment.

The structure supports the load carrying idlers and the return (empty belt) idlers. The former are either of the fixed troughing type, normally set at 30°(Fig. 3-25), but for special or high capacity narrow belts can reach 45°, or of a flexible or variable trough type in which the troughing angle steepens as the load increases (Fig. 3-26). Return idlers are usually flat (Fig. 3-25).

(c) Conveyor Belting

The belting used for modern underground coal mine conveyors is always fire resistent or fire proof and can be categorised by the mode of construction. The three principal types in use in underground coal mines today are:

- Synthetic or natural woven fibre belts
- Steel cord reinforced belts
- Cable belts

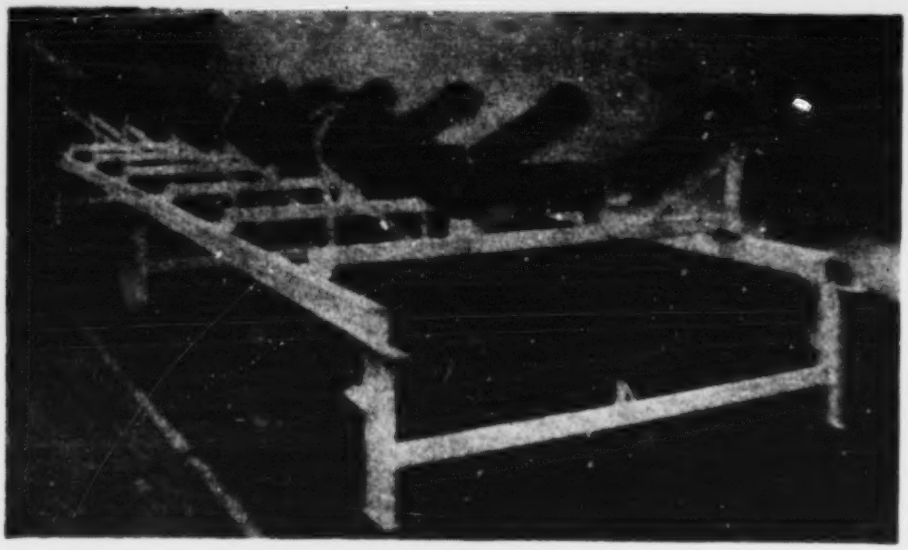


FIGURE 3-23 RIGID CONVEYOR STRUCTURE

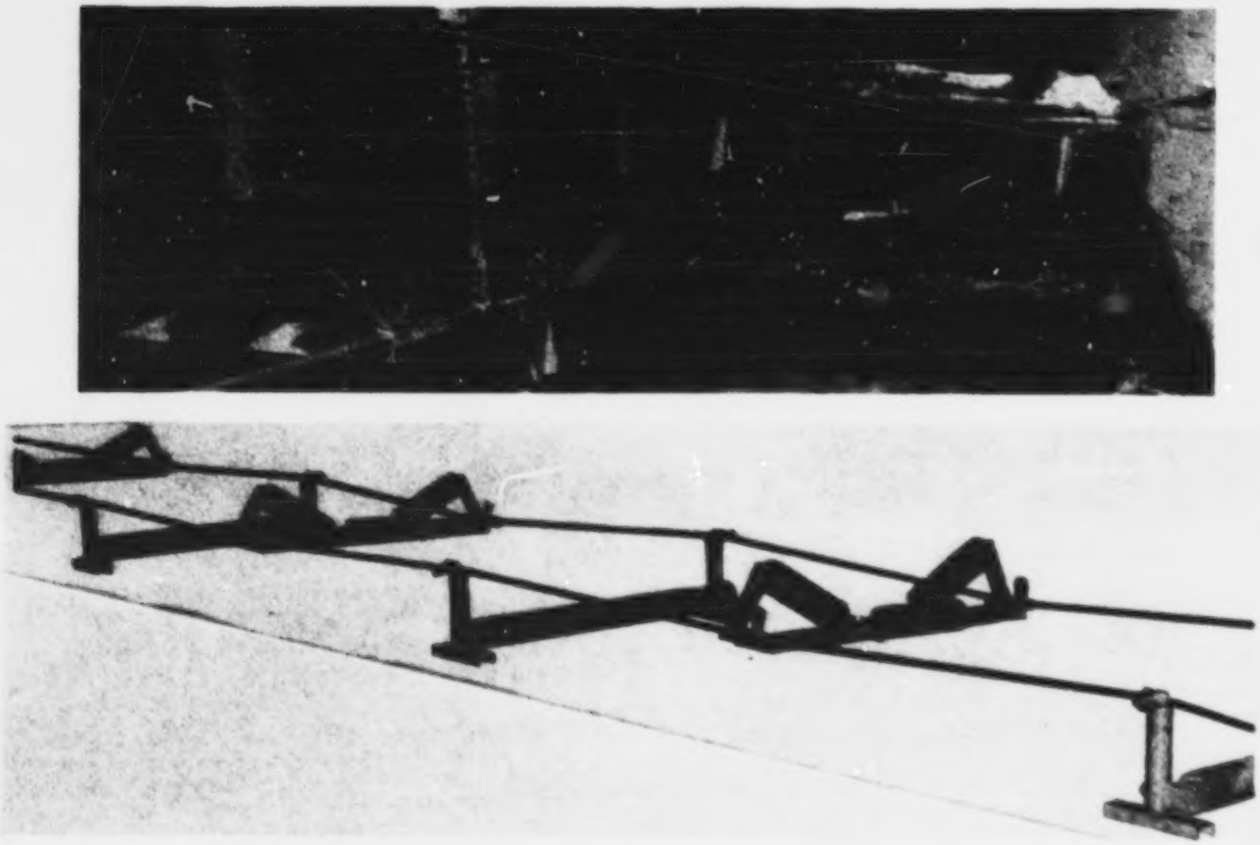


FIGURE 3-24 ROPE SUPPORTED CONVEYOR STRUCTURE

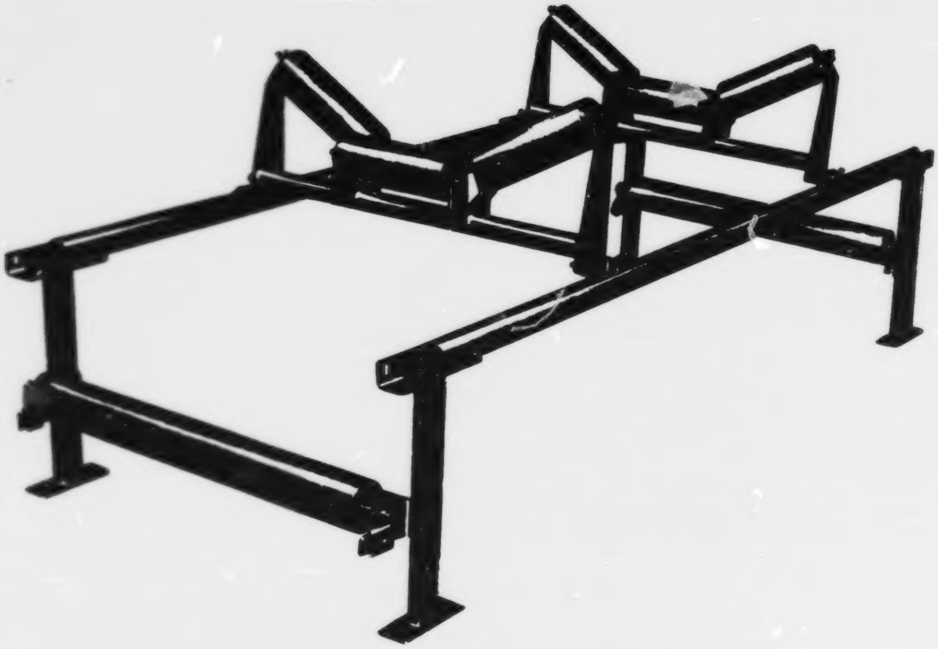


FIGURE 3-25 FIXED TROUGH IDLERS AND FLAT RETURN ROLLERS

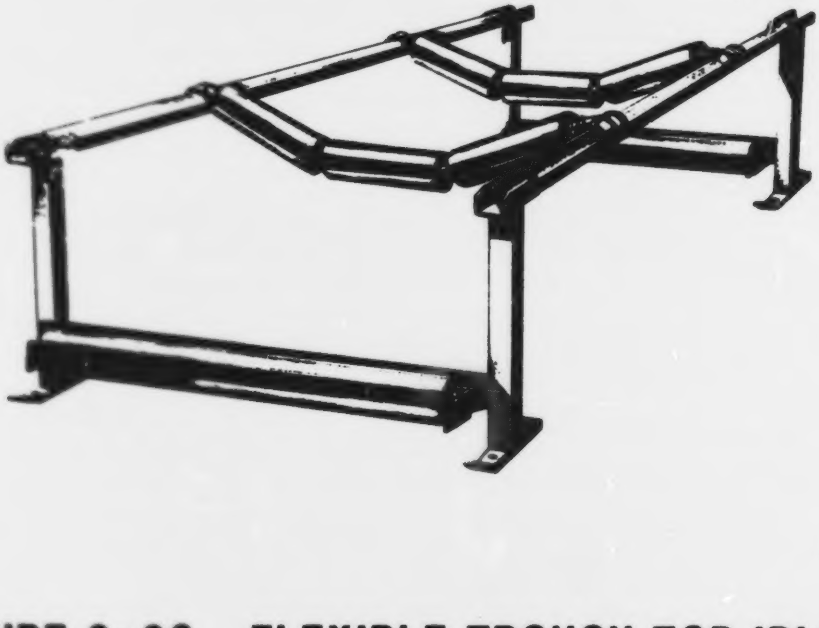


FIGURE 3-26 FLEXIBLE TROUGH TOP IDLERS

(i) Synthetic belt

A major contributing factor to the improved reliability and popularity of long, high capacity trunk conveying systems has been the development of high tensile fire and oil resistant belts and improvements in the techniques for making joints. The use of extremely strong synthetic fibres as a primary carcass material instead of natural fibres has allowed the belt thickness for any given strength to be reduced, which in turn has increased belt flexibility and enabled greater troughing angles to be used (up to 45°). This in its turn has increased the coal carrying capacity of the belts. The woven carcase usually comprises continuous filament, synthetic fibre in the longitudinal stress members and the transverse yarns, together with a series of staple fibre yarns interwoven to give increased protection and resistance to abrasion and general wear and tear (Fig. 3-27). PVC is normally used for the impregnation and cover material. This gives a solid impregnated belt of belt strengths up to 2000 kN/m with the highest degree of fire resistance, and yet offering good flexibility.

A new generation of high tenacity fibres (aramides) has been recently introduced, which now enables new solid woven belts (Kevlar) with belt stengths up to 4000 kN/m to used. Other advantages brought about by the introduction of high tensile strength belts is that it has allowed more powerful drives to be used and increased the maximum flight length and has produced lighter weight belts permitting lower running powers and costs.

(ii) Steel Cord Belts

The steel cord belt first appeared in the 1940's in the USA as an attempt to increase the strength of conveyor belting and hence permit longer hauls, higher lifts and greater horsepowers.

The strength of conveyor belts is increased by moulding steel cords longitudinally into the belt material (Fig. 3-28). They allow conveyor flights to extend to approximately 2.5 times that of the highest quality fibre belts. Additionally, as steel cord belts have low elongation properties even when used with very high output drives, they can be used with

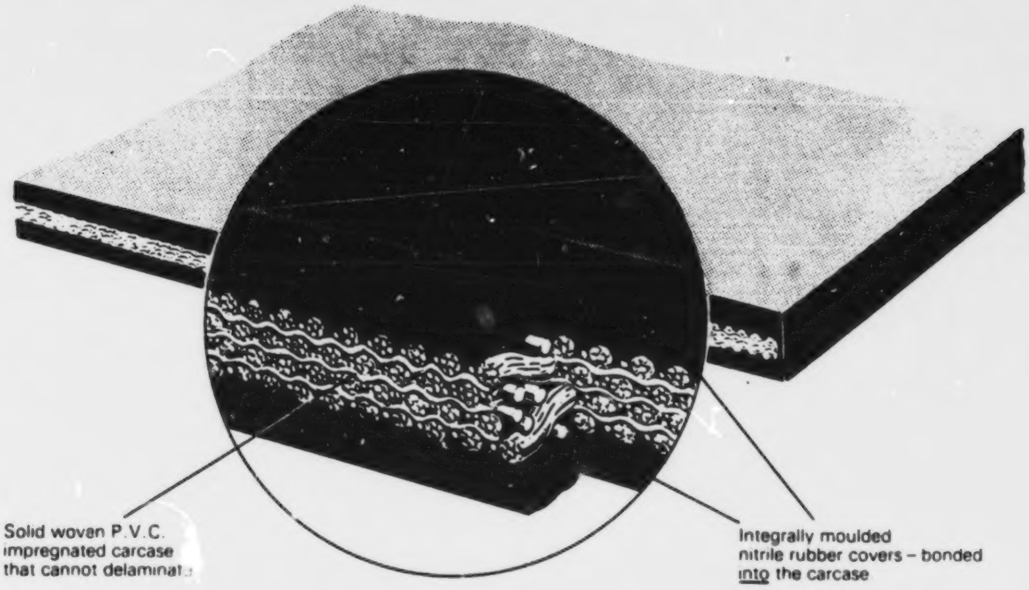


FIGURE 3-27 SOLID WOVEN BELT CONSTRUCTION

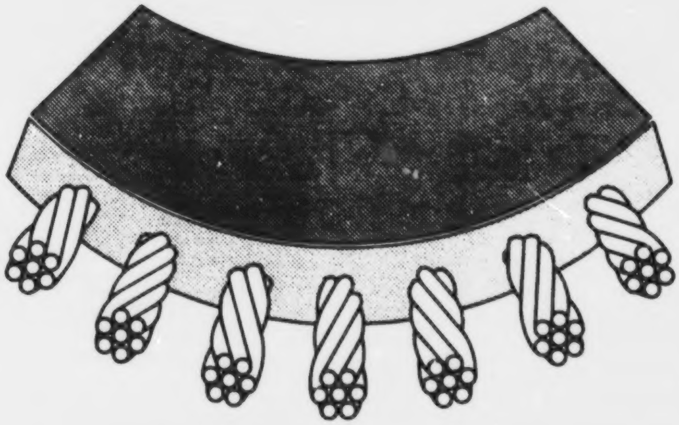


FIGURE 3-28 STEEL CORD BELT CONSTRUCTION

FIGURE 3-29 SPLICING STEEL CORD BELTING

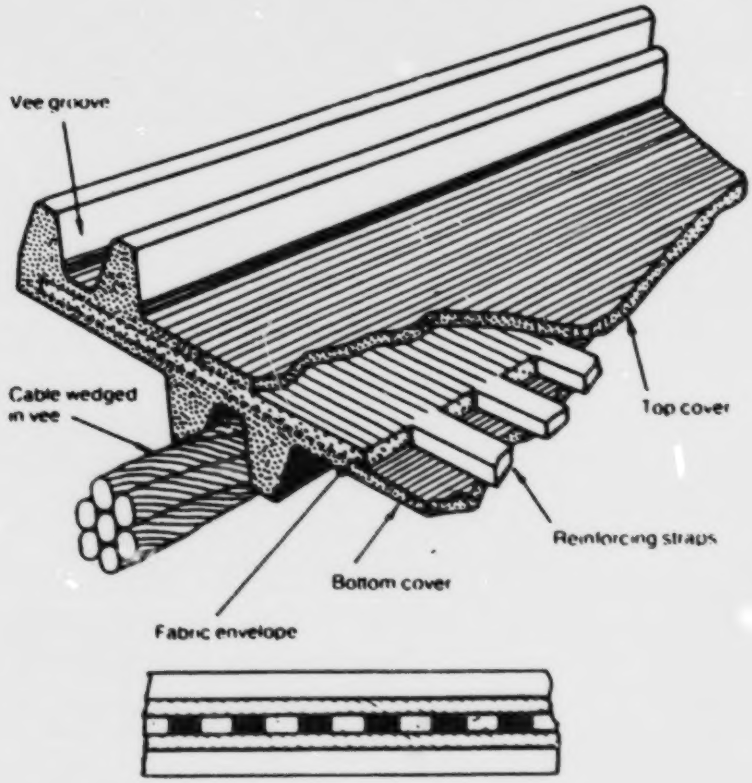


FIGURE 3-30 MODERN CABLE BELT CONSTRUCTION

TABLE 3-2

Properties of Conveyor Belting

Type	Min. Warp Strength (kg/cm)	App. Min. Weight (kg/m^2)	Thickness (mm)	Elongation at Break
FABRIC SOLID WOVEN				
Pvc				
6	1160	14.75	12	15-30%
8	1430	15.30	13.5	
10	1790	18.58	14.5	
12	2150	19.13	15.0	
15	2687	20.00	15.5	
20	3582	n.a.	n.a.	
Kevlar				
T2000	2000	22.00	13.0	2-4%
49	4000	35.00	19.0	
STEEL CORD BELT				
1150	1150	20.5	14	2-3%
1400	1400	22.5	15	
1600	1600	23.5	15.3	
2000	2000	24.5	15.6	
2500	2500	29.4	17	
3500	3500	39.0	22	
4000	4000	42.6	23	
7000	7000	n.a.		

short belt take up loops. However, perhaps the greatest advantage of the steel cord belt is its joint efficiency, and the fact that properly made joints never tend to open up and strip back as do textile belts (Fig. 3-29). This allows lower factors of safety (7:1). The belt is flexible in both the longitudinal and transverse directions which in turn permits smaller diameter pulleys to be used. Steel cord belting, although considerably more expensive than fibre belting, is now available in strengths up to 7000 kN/metre and up to 1800 mm in width.

(iii) Cable Belt

The cable belt is a unique conveyor system in which the functions of carrying and driving are separated. The system is described in more detail in Section 353.1. Essentially the belt has only to carry the load, the driving forces are provided through the steel cables which support the belt. In this way, the tension in the belt is minimal since it has been relieved of the duty of drive transmission. The cable belt is a laterally rigid, but longitudinally flexible belt supported at or near its edges on two parallel endless loops of drive cable. When empty, the belt runs flat, but when loaded, it assumes a natural troughing caused by the weight of coal. The belt has continuous 'V' form grooves moulded along either side, top and bottom, to suit the cable diameters (Fig. 3-30). Transverse steel stiffening is moulded into the belt which limits the loaded troughing to 15%.

(iv) Belt Tensioning

In all conveyor systems, some system has to be provided to ensure that the correct belt tension is maintained in the conveyor belt under all load conditions. In the high-horsepower, fixed length permanent conveyor, this is often achieved by gravity weights. In most other conveyor systems, the tension is maintained by sensing devices in the loop take-up or storage unit which signal the loop motor to take in or let out belting stored in the unit, so that the belt tension can be maintained within preset limits.

353 NON-CONVENTIONAL CONVEYOR DRIVES

The need to carry greater tonnages over longer distances through larger vertical lifts, has led not only to the developments in conveyor belting described previously (352) but also has resulted in a number of different drive configurations to the standard or conventional drives.

These are:

- Cable belt systems
- Booster, Linear or T-T systems
- Wheel Assisted systems

.1 Cable Belt systems

The cable belt conveyor comprises two endless steel driving cables which support each side of an endless loop of belt. The endless belt has two continuous grooves at its edges, one on the upper surface and one on the lower surface (Fig. 3-30). The amount of deflection varies from zero when empty to up to 15% when fully loaded. No continuous structure is required for the cable conveyor, only pulley stands at suitable centres to ensure the correct vertical and horizontal alignment of the drive cables (Fig. 3-31).

These steel cables are driven by large diameter friction wheels mounted on either side of the drive unit (Fig. 3-32). A differential gear is incorporated into this drive unit to ensure that each wheel maintains the same peripheral speed and that the power transmitted to each cable is equalized. The driving cables are tensioned independently, and separately from the belt, thus enabling any variation in stretch to be accommodated.

The conveyor driving unit can be placed at any point in the system, although it is usually to be found at the head end. Drives of up to 9000 kw transmitted through 57 mm diameter cables are now in operation.

Two further points of interest are that the material being carried on the belt is not subject to any significant movement (no rollers) allowing the coal to retain its natural surcharge angle with consequent maximum capacity, and the cable belt can negotiate curves, or through the use of angle stations, sharp changes in direction. In the latter case, the ropes are deflected through a series of angled pulleys to continue the drive in the new direction (Fig. 3-33).

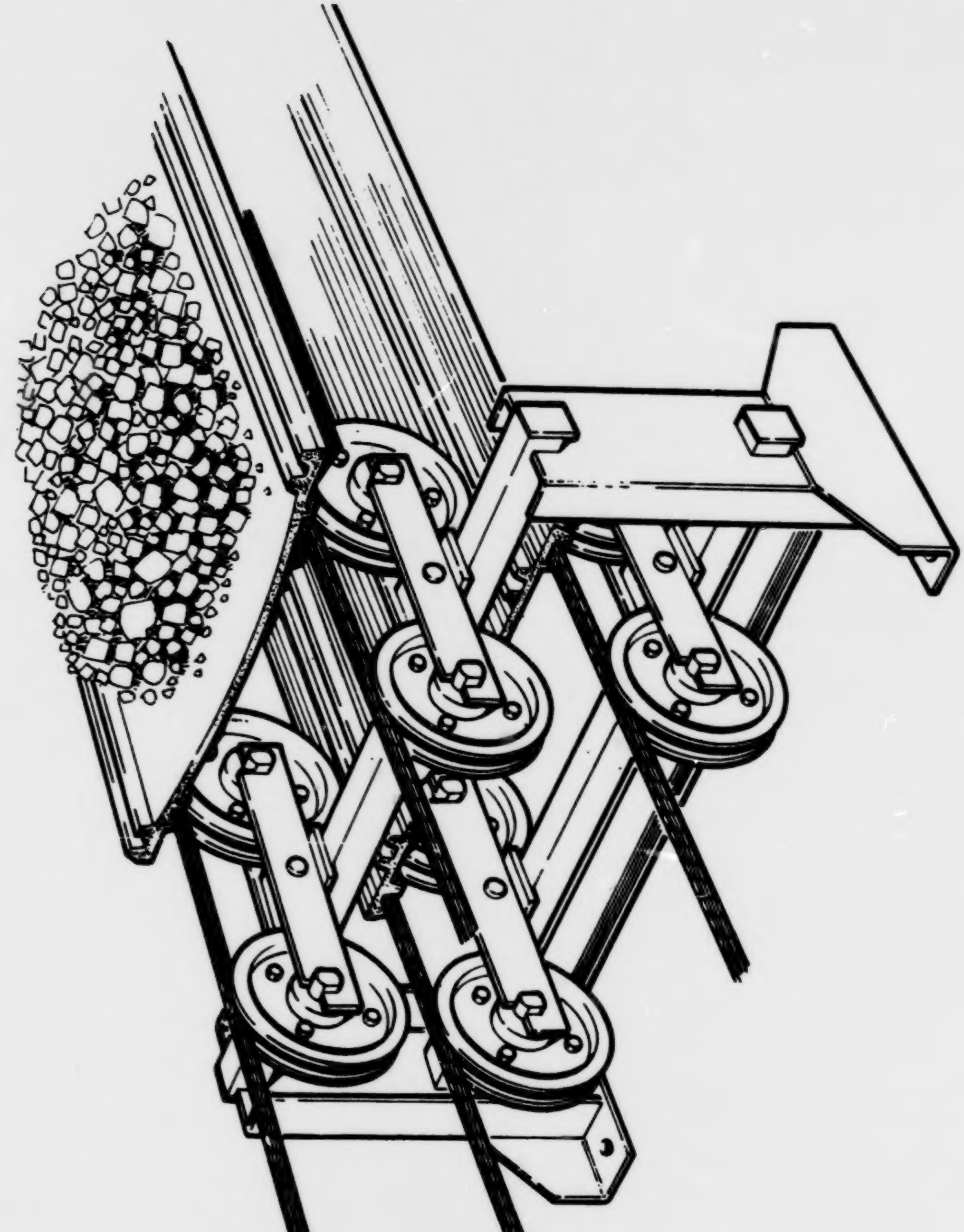


FIGURE 3-31 TYPICAL 8 PULLEY LINESTAND

Cable belts are being used on haulage systems over 50 km in length, with 1000 m of vertical lift, or with capacities over 2000 tph.

.2 Booster Drives

Variously called booster drives, linear drives, intermediate drives or T-T drives, and although the idea was patented in the U.S.A. in 1917, these were developed in Europe in the mid 70's to add additional power to an existing conveyor system, or to reduce the power of the drive units in a new system. This extra power is transmitted to the belt in a linear fashion through friction contact with the main belt. The power transmitting element is an endless belt which is in contact with the underside of the main belt, and which is itself driven by a conventional drive unit. This form of power transfer does not disturb the carrying surface of the belt, thus booster conveyor drives can be easily added to existing systems (Fig. 3-34).

The major advantage is that for a given total power in the system, the belt tension is considerably reduced (Fig. 3-35). The use of the booster drive means that a high horsepower long length conveyor can be constructed as a single flight but with several small standard conveyor drive units instead of one large special high horsepower drive unit.

Other advantages are reduction in underground space requirements and the capability of using lower specification and hence less expensive belting.

.3 Wheel Assisted Drives

An unusual design of mainline conveyor belt has been introduced into at least two mines in the USA. It is an intermediate or booster conveyor drive system which utilizes a novel concept and two simple components. These are a specially designed radial tire drive module and a matching or complimentary conveyor belt (Fig. 3-36). The conveyor belt is a normal fabric unit reinforced longitudinally by steel cables however, unlike conventional steel cord belts, these cables are only embedded in rubber flanges on the outer edges of the belt. The rubber drive tires are pressed firmly on these flanges and act as power application or transfer points enabling the power from the electrically driven tires to be transmitted to the conveyor belt at any point along its length. These intermediate drive units normally consist of four driving tires, four free wheeling or pressure tires and two rubber covered pressure rollers. The driving tires are powered by a 100 to 150 kW motor and transmit this power to the conveyor belt by contact of the driving wheels pressing on the outside flanges of the

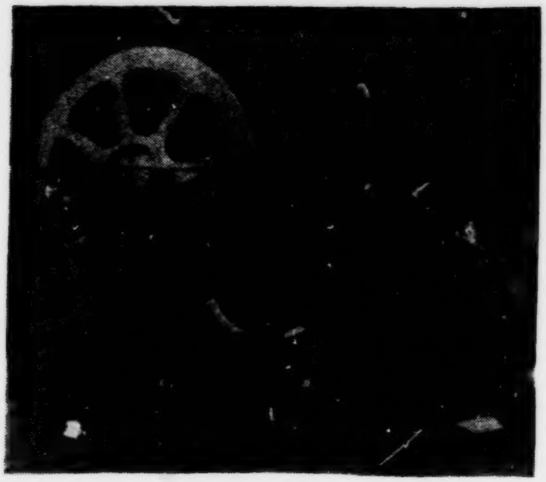


FIGURE 3-32(a) 3000kW FRICTION WHEEL DRIVE FOR A CABLE BELT CONVEYOR

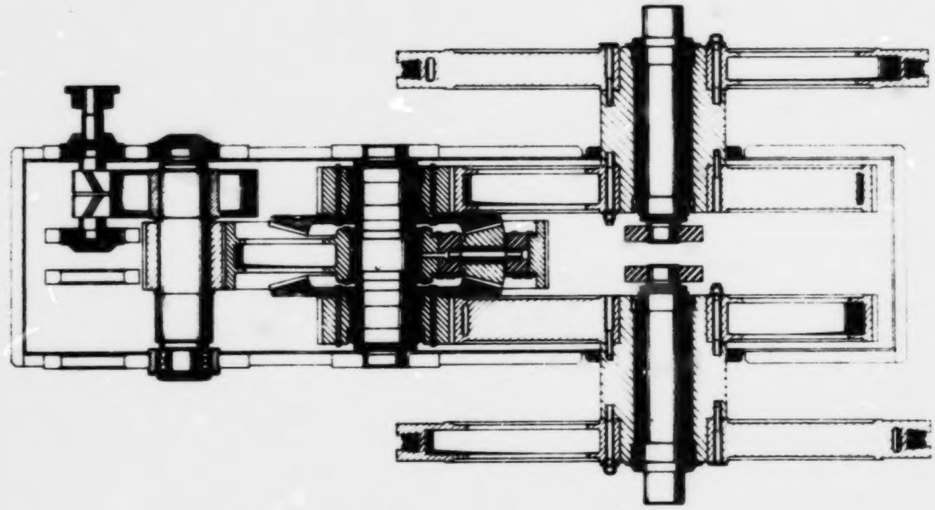


FIGURE 3-32(b) CURRENT GEARBOX

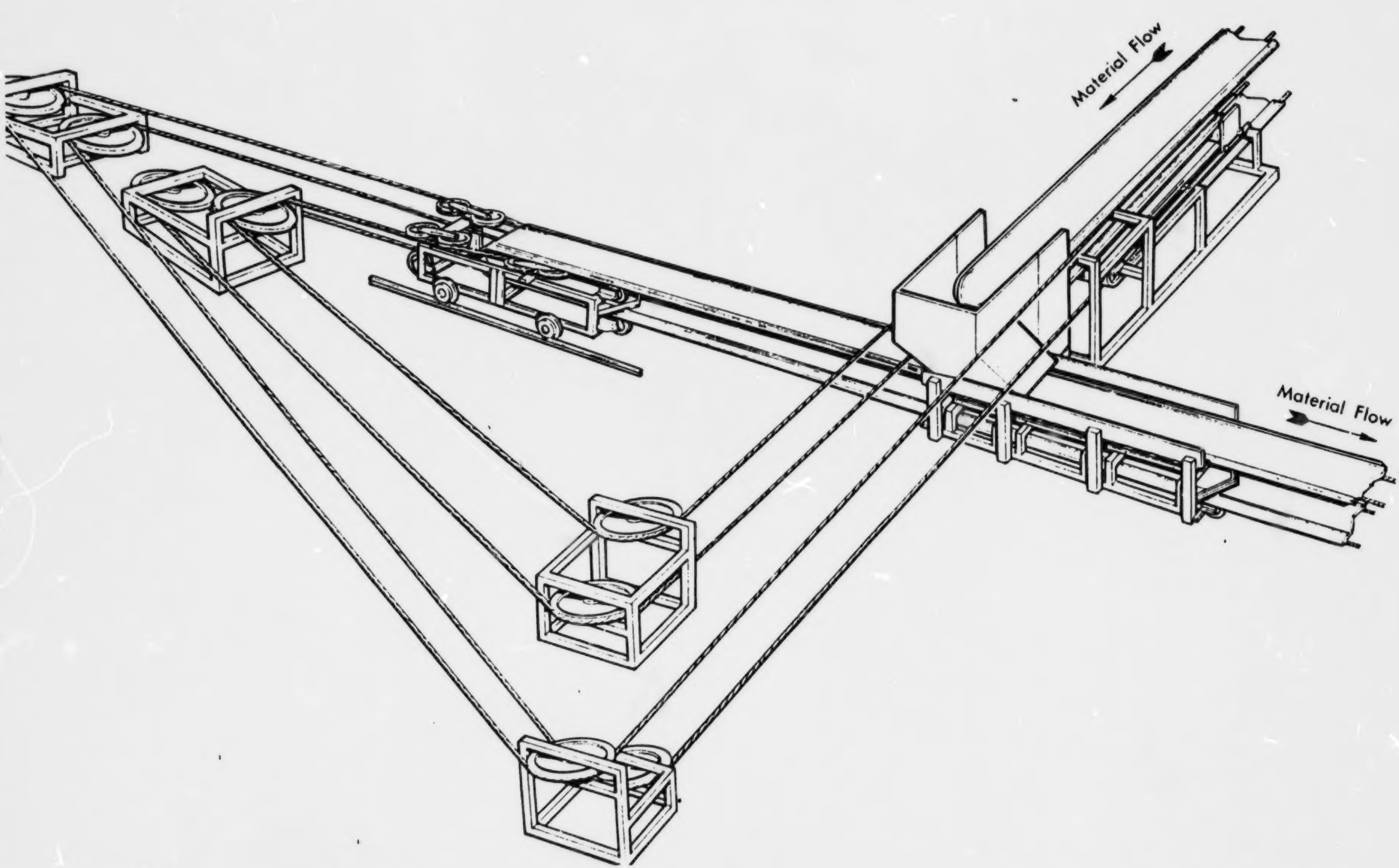


FIGURE 3-33 CABLE BELT ANGLE STATION

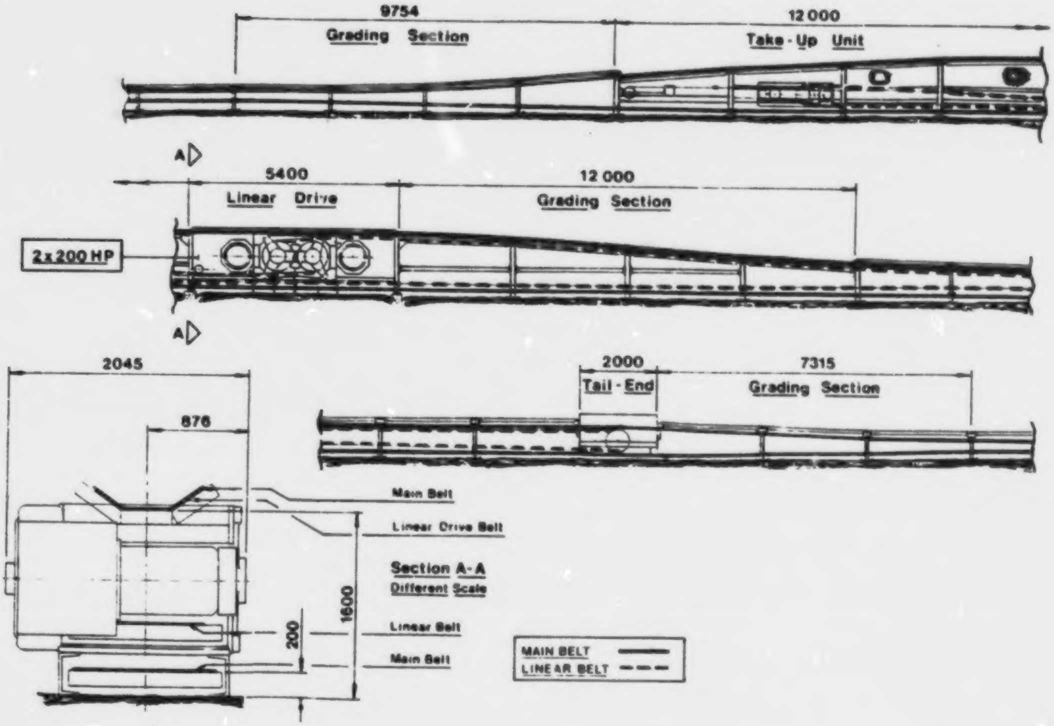


FIGURE 3-34 TYPICAL ARRANGEMENT OF LINEAR DRIVE CONVEYOR USING CHIEFTAN 2x200HP

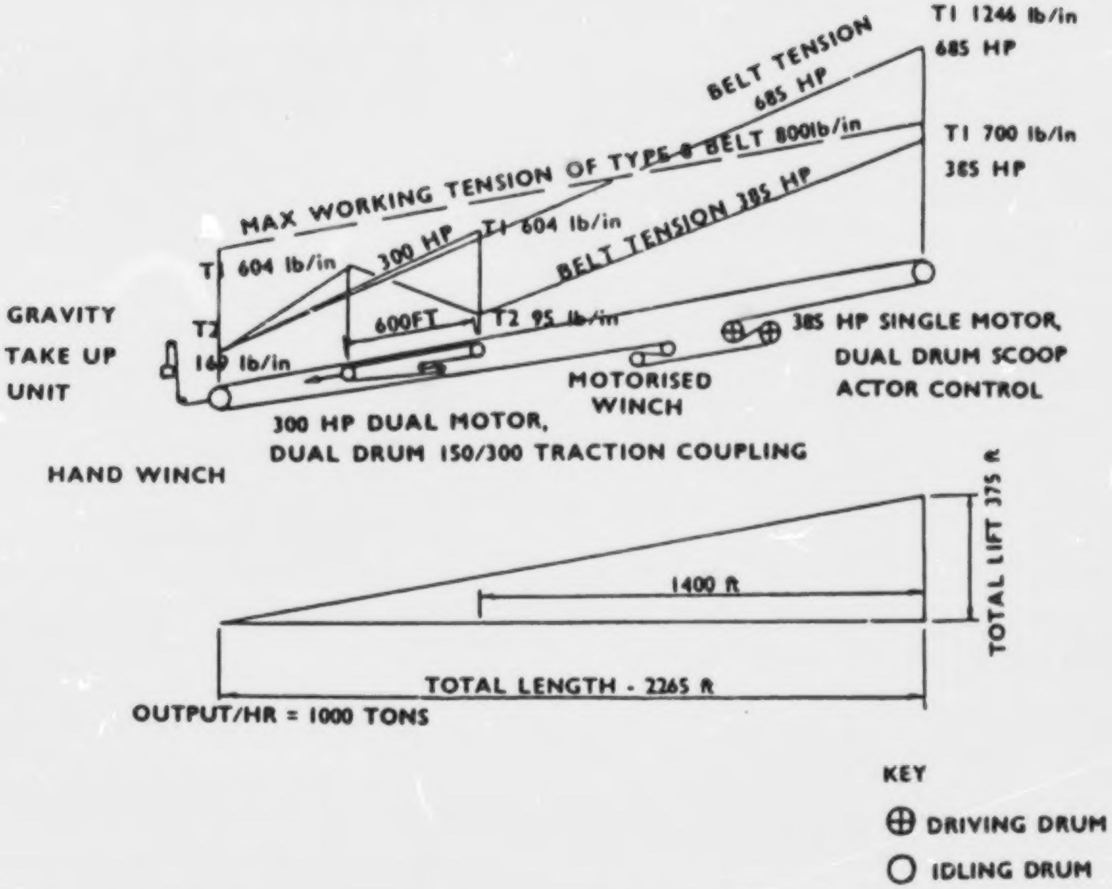
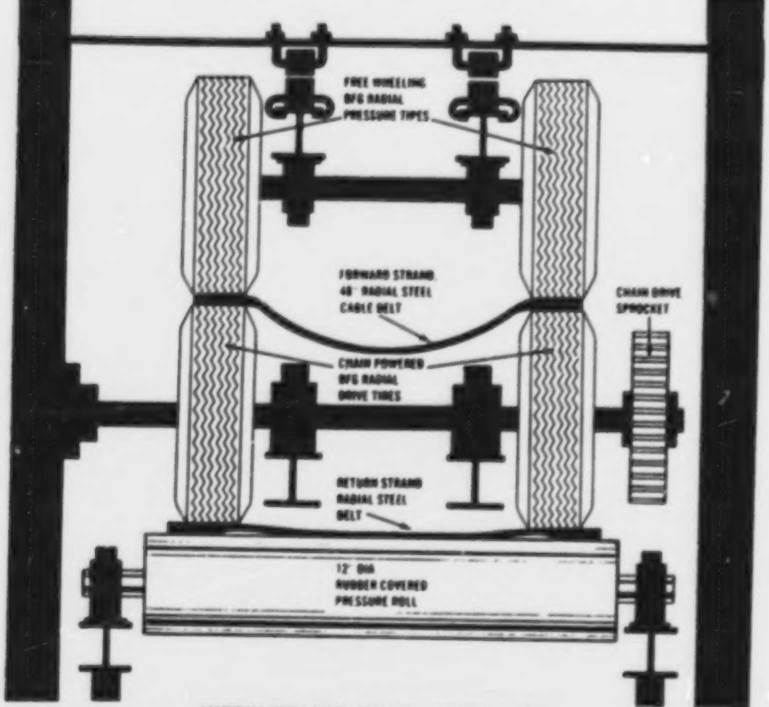


FIGURE 3-35 COMPARISON OF BELT TENSIONS WITH AND WITHOUT BOOSTER DRIVES

INTERMEDIATE DRIVE (END VIEW)



INTERMEDIATE DRIVE (SIDE VIEW)

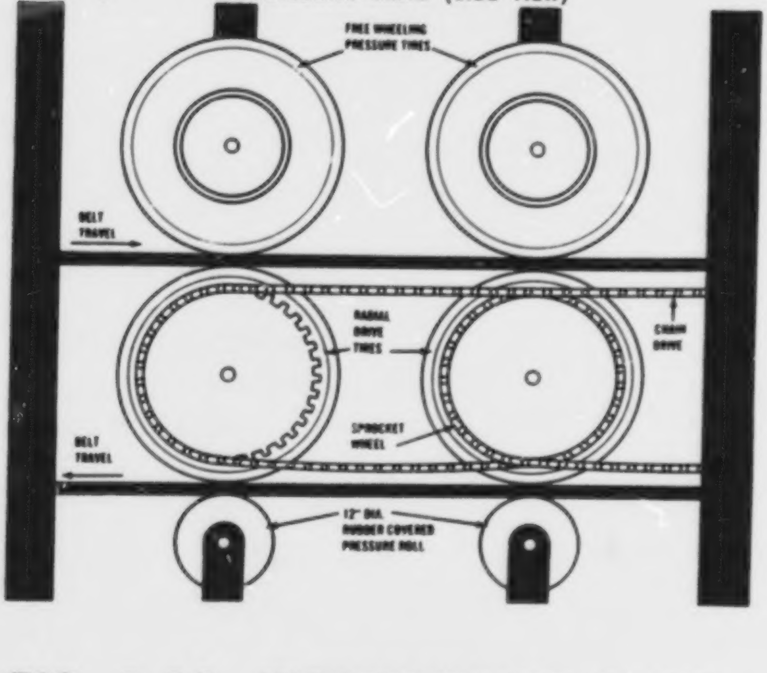


FIG 3-36 INTERMEDIATE DRIVE USING TIRE DRIVE

conveyor belt. Because the power units can be positioned at suitable intervals along the conveyor belt only minimum extra tension is applied to the belt. In theory, that there is no straight line distance this conveyor design would not cover as a single flight belt and without transfer points. The longest known installation has a single flight of 2000 m however the manufacturers are already developing conceptual designs to increase this to 15 km and ultimately 25 km.

354 BELT CLEANING

One of the most important factors in maintaining good belt conditions and reducing fire hazards and belt and idler damage, is the cleanliness of the return belt.

It is necessary not only to prevent carry back of coal fines, but also to eliminate the need for hand cleaning of transfer points and other areas where fines collect.

The most efficient method is to remove the fines from the return belt immediately after the discharge pulley.

Various methods are available for achieving this, utlizing scrapers, rotary brushes, wet sprays and various combinations. A typical system will include (Fig. 3-37) an in-chute scraper and two or three scrapers or brushes behind the head pulley. If the belt is very wet, several oscillating (mangling) rollers may be necessary.

The fines which drop from the conveyor are collected in a receiving section from where they are fed onto the next conveyor outbye the transfer point. This can be carried out by either a tray with a reciprocating ram pusher (Fig. 3-37), or a tray with a continuous chain conveyor, or a hopper with a worm-type screw conveyor (Fig. 3-38).

The latest developments in this field have been incorporated into the steel cord belt conveyor at the Selby Mine in the U.K. (Fig. 3-39). This comprises (Fig. 3-40), a set of spring scrapers immediately behind the drive pulley, followed by a belt washing unit and vacuum extraction unit behind the snub pulley. The solids collected by the scrapers are discharged by screw-fed hopper, and the slurry from vacuum and washing units is treated in a cyclone plant. This is described in more detail in Appendix B.

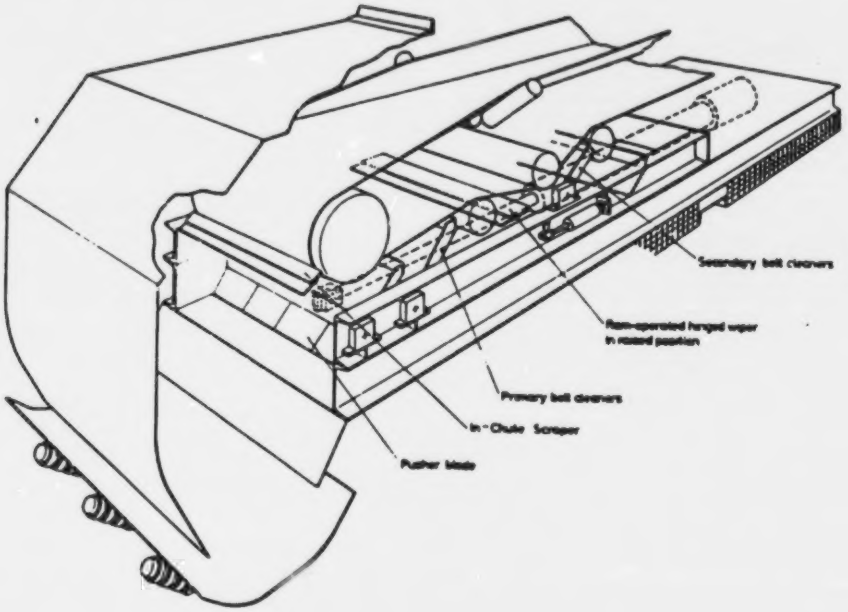


FIGURE 3-37 BELT CONVEYOR TRANSFER POINT FINES CLEANING SYSTEM

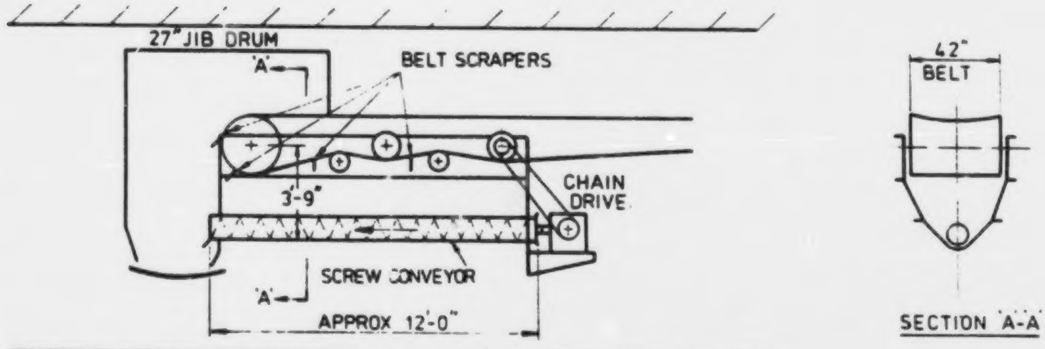


FIGURE 3-38 ARRANGEMENT OF SCREW CONVEYOR & FEED CHUTE

355 CONTINUOUS SECONDARY COAL TRANSPORT (CONVEYORS)

A reliable and continous flow of coal from a coal producing machine is essential if that machine is to achieve its full capability. When trackless vehicles such as shuttlecars are used to transport coal from a continuous miner at least 20% of the potential production from the continuous miner is lost while the miner waits for the shuttle cars to complete their journey or change. The introduction of continuous haulage systems to connect the mining machine and the panel transportation is eliminating this bottleneck. Additionally considerable improvements to the safety of personnel result from the reduction in the movement and number of vehicles, particularly shuttle cars, that are used near to the coal face when they are replaced by continuous haulage systems. The ideal continuous haulage system has three basics:

1. High capacity, capable of accepting the instantaneous and continuous production from a continuous miner.
2. Mobility so that it can follow the continuous miner.
3. Compatibility. The system must not interfere with other key mining or ancilliary operations.

Continuous haulage systems under development at present include multiple belt and chain conveyor in series flexible conveyors and hydraulic and pneumatic pipelines and hydraulic gravity systems. To date full acceptance of all of these systems has been somewhat limited even though considerable success has been achieved with some of them at specific locations. Although they are often considered to be embryonic, some developing continuous coal haulage systems are reported to have improved individual coal producing machines output by up to 100% over that achieved using conventional shuttle car coal transportation systems.

356 GENERAL ADVANTAGES AND DISADVANTAGES

The main advantages and disadvantages of the belt conveyor transportation system are listed below.

Advantages

1. Coal transportation is continuous.
2. Can operate on steeper and more variable gradients than most other systems.
3. Simple to automate and control.

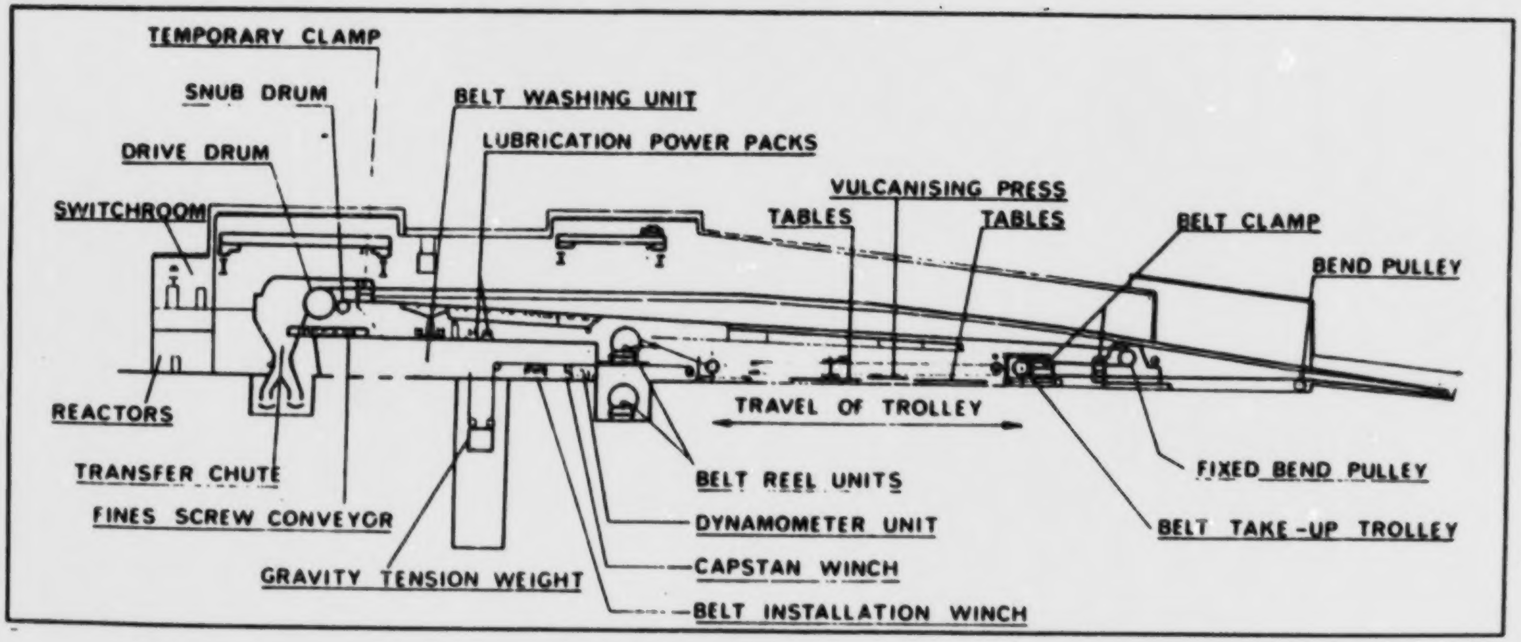
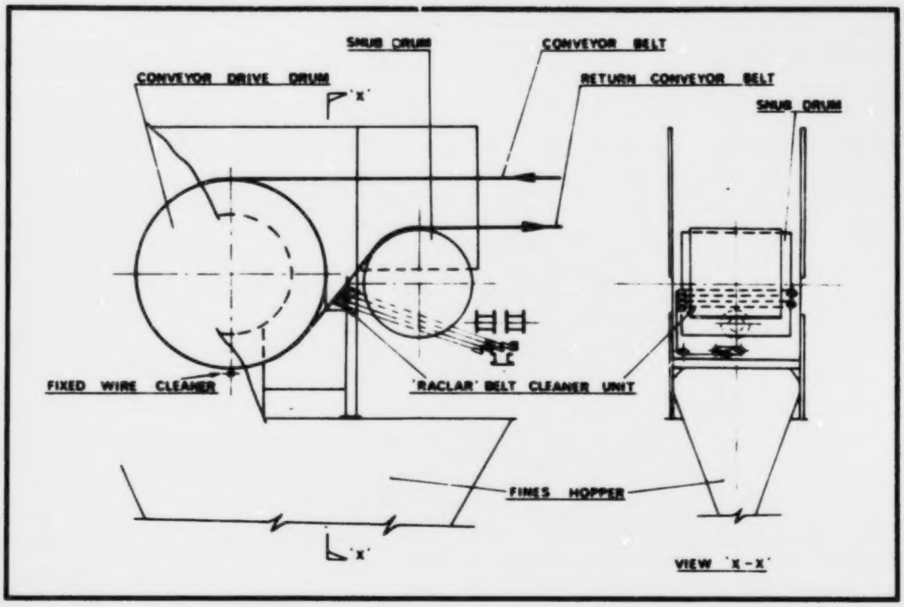
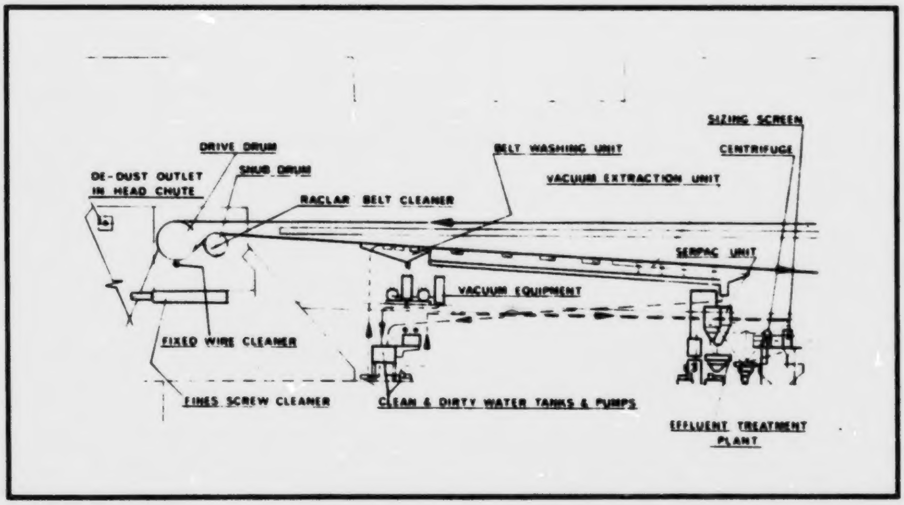


FIGURE 3-39 SELBY MINE STEEL CORD CONVEYOR DRIVE SYSTEM



(a) SCRAPERS AT HEAD END



(b) BELT WASHING ARRANGEMENT

FIGURE 3-40 SELBY BELT CLEANING SYSTEM

4. High capacity system.

5. Remains fixed in roadway thus requiring minimum operating clearances.

6. Safer than other systems in respect of personnel accidents (excluding manriding).

7. Can provide the complete secondary and primary haulage system in a mine from face to surface.

Disadvantages

1. Even with the use of fire resistant belting still represent a major fire hazard.

2. Cannot easily negotiate changes of direction without transfer points.

3. Can be adversely affected by floor heave or roof deterioration.

4. More expensive to extend than most other systems.

357 MONITORING, CONTROL AND AUTOMATION

It is in this area that developments have taken place which are bringing belt conveyors to the forefront for coal transportation underground.

With the ever increasing cost of labour, the labour intensive requirements of conveyor systems, especially at loading and transfer points, and the high accident rate to personnel, great emphasis is now placed on the automation or remote control of conveyor systems. Technology has now advanced to the stage where conveyor systems can be automated, and remotely controlled and their functions monitored continuously throughout their length.

Monitoring generally covers three areas:

- operational - belt speed, slip, alignment, blocked chute, etc.
- conditional - temperatures, fluid levels, etc.
- general - signals and communications.

.1 Operational Monitoring

The following conditions are usually monitored in a conveyor system using some form of transducer or switch.

a) Belt Tension

The level of belt tension is selected at the design stage. It is measured by a dynamometer in the loop take up winch circuit, and can be monitored to operate between preset tension limits. Adjustment takes place automatically.

b) Belt Alignment

Excessive deviation of the belt can cause spillage, and if it occurs in driveheads and tail ends, damage to the belt can occur. Belt alignment switches detect and react to the problem to rectify it.

c) Belt Slip

Heat is generated when a belt slips. Speed sensitive devices are used which are preset to provide warning if the speed drops to a predetermined proportion of the nominal belt speed. These switches also form part of the belt sequence control system.

d) Torn Belt

Damage to the edge of the belt is detected by means of trip wires under the belt.

e) Blocked Chute

A blocked chute can cause damage to both belts at the transfer point. Detection devices are placed in the chute and adjacent to the discharge pulley.

.2 Condition Monitoring

a) Temperature and Fluid Levels

The health of drive units, return ends, loop takeups is usually monitored through the temperature of bearings, fluids in gearboxes and couplings, and by fluid levels in gearboxes and tanks.

b) Position Indicators

Brakes and fluid couplings are important to the effective working and control of a conveyor drive head.

Limit switches with monitored position are used to indicate whether brakes are on or off, scoops on fluid couplings are in or out, and the amount of brake lining wear.

On inclined conveyors, a torque responsive brake is used. This ensures that the drive motor takes the load before the brake is released.

.3 General Monitoring

Signalling systems are required to provide a reliable method for stopping the belt conveyor. These systems take the form of an extended loop or lock out circuit along the length of the conveyor system which provides pull wire stop facility at any position and lock out switches at regular intervals. Recent systems now have the capability to indicate the location at which the system was locked out.

Communication is also vital. The lock out unit usually incorporates a loudspeaker system, which is connected to the control room and allows two way communication throughout the system.

Communication is an aid to greater productivity and safety, providing the ability to inform people of problems and thus minimize operational delays. The operational safety is improved by the incorporation of a pre-start warning device, which broadcasts an audible warning throughout the length of the conveyor prior to its being started.

.4 General

The effective monitoring and control of belt conveyors relies on the extensive use of transducers which protect both plant and personnel from the effects of receiving a system when condtions are unsafe.

The majority of protective transducers are in the form of segregated switch contacts, limit switches or thermal switches.

.5 Control

Comprehensive control schemes for conveyors require a signalling system, a communications system, transducer monitoring and a control system.

Control systems must provide facilities for local control, remote control, and where required, surface control.

Such systems typically consist of a master station (usually situated in the colliery surface control room), and a number of underground outstations. The surface operator can control all of the underground equipment connected to the outstations. The master station has comprehensive visual displays which keep the operator informed of conditions underground, including the state of the plant being controlled. Faults are also displayed and logged on to a print out.

The link between the surface and underground stations is a single four core telephone cable which runs from the masterstation to the first outstation and then to the remaining outstations in turn.

Full local control can be selected at the outstations, and even when surface control is in operation, the local 'stop' controls overide any control signals received from the surface.

The master station has its own microprocessor controlled circuitry, and each outstation has its own microprocessor for the control and monitoring functions for the associated plant. It transmits and receives data to and from the surface masterstation.

3.6 HYDRAULIC TRANSPORTATION

361 INTRODUCTION

The definition of hydraulic transportation is a system which uses water as the transporting fluid.

The first use of hydraulic transportation in coal mines utilised gravity to transport coal in open flumes. Today gravity and pumped systems although not widely used, have been sufficiently applied to prove that they can have distinct safety, operational and economic advantages when mining conditions and mine layout are suitable. It is usual to employ open, natural gravity flow, flume systems for coal transportation in full scale hydraulic mines and this has proven to be very successful. Similar systems are being used in room and pillar and longwall mines, particularly in the USSR. Flumes, however, are directly dependent on natural gradient for coal-water slurry flow and therefore have a smaller field of application than pumped pipelines which can safely transport coal at any gradient from flat to vertical.

Hydraulic transport of coal by both gravity and slurry pumping systems is currently being used in USSR, USA, Canada, Japan and China. The method has been used for main transport systems from underground to surface, for secondary collection systems, and direct from the mining machine to the surface.

362 GRAVITY TRANSPORTATION SYSTEMS

The gravity system consists simply of a series of flumes through which water carrying coal travels. Water and coal are introduced into the flumes, which require a minimum gradient of 4° to work effectively, and are transported either out of the mine by gravity or to the lowest point of the mine where it is then handled by a slurry pumping system.

The gravity hydraulic transportation system requires the following equipment. (1) A low head high volume pump on the surface, which delivers water at 75-150 litres/second along a pipe range to the coal producing machines or face. (2) A coal/water mixing unit at the face or heading into which the coal and water are discharged at an approximate 50% solids/liquids ratio. (3) A U-shaped flume or trough placed on the roadway floor at a minimum gradient of 4°-7° dipping away from the production face or heading. If the flume is steel, the critical gradient is 6°-7°, whereas it drops to 4° if the flumes are lined with low friction material. The flume system delivers the coal/water mixture to either the surface if elevations are suitable or to the sump in the lowest part of the mine for onward transport by the slurry pumping system or after dewatering by conventional systems.

Dependent on the size of coal produced by the production unit, the coal/water mixing unit may be replaced by a feeder/breaker unit to ensure that the coal is acceptable to the system (-150 cm).

Provided sufficient water is available, and the gradients are suitable, gravity flume systems can handle considerable quantities of coal. Recent achievements in a hydraulic mine in B.C., reached outputs of over 120,000 tonnes in a single flume system in a month.

363 SLURRY PUMPING SYSTEMS

The development and utilization of the hydraulic coal-water slurry transportation systems in North America has been relatively slow, the first modern underground hydraulic coal-water slurry pipeline transportation system in the USA being installed at the Robinson Run Mine in the early 1970's. In these trials the coal was initially transported in a shuttle car from the continuous miner to a fixed crusher from where it was introduced to a pump and into a rigid pipeline system. As this system was developed further, the shuttle car was eliminated and the slurry preparation unit, consisting of a mobile crusher, mixer and injection pump, was towed directly behind the continuous miner and collected the coal from the continuous miner for pumping out of the mine as a slurry to the surfce coal preparation plant. During the Robinson Run Mine tests up to 480 tph of coal were successfully transported to the coal preparation plant. The production and economic benefits of this embryonic system were encouraging and a full scale production system has since been successfully installed at the Loveridge Mine where hydraulic pipeline transportation is being used as a key part of both continuous miner and longwall operations. The main longwall slurry system and the mine to surface slurry pumping system has already pumped several million tonnes of coal to the coal preparation plant at up to 150,000 t/month.

In Canada a full scale hydraulic coal mine has been operating since 1970 and has achieved remarkable safety and economic results. It has already produced and transported almost 10 million tonnes of coal to the preparation plant. In the Soviet Union hydraulic coal mines have been sucessfully operating for approximately 30 years and today produce approximately 10 million tonnes per year of both thermal and metallurgical coal, some of which is pumped directly from within the mine to electrical power generating plants. In Japan a hydraulic transportation system has been successfully transporting coal in a very deep and gassy mine for over 20 years. Thus in Canada, USA, USSR and also China, hydraulic coal-water slurry transportation systems have been transporting coal out of mines with reduced accidents, improved productivity and reduced operating costs.

The slurry transportation system consists essentially of a clean water storage and pumping system on the surface; pipelines to conduct the clean water to either the production units, or the slurry storage sump; a sump(s) to store the coal water slurry; slurry pumps including controls, and pipelines to the surface to carry the coal/water slurry (Fig. 3-41).

Additional equipment may include screens, dewatering units and storage bins, if the coarse coal fraction is separated out and transported out of the mine by conventional means (conveyors, locomotives), whilst the fines fraction (-10 mm) is transported through the slurry line.

The numbers and sizes of the sumps, pipelines and pumps are dependent on the production rates, surge rates, and length and lift over which the coal is to be transported.

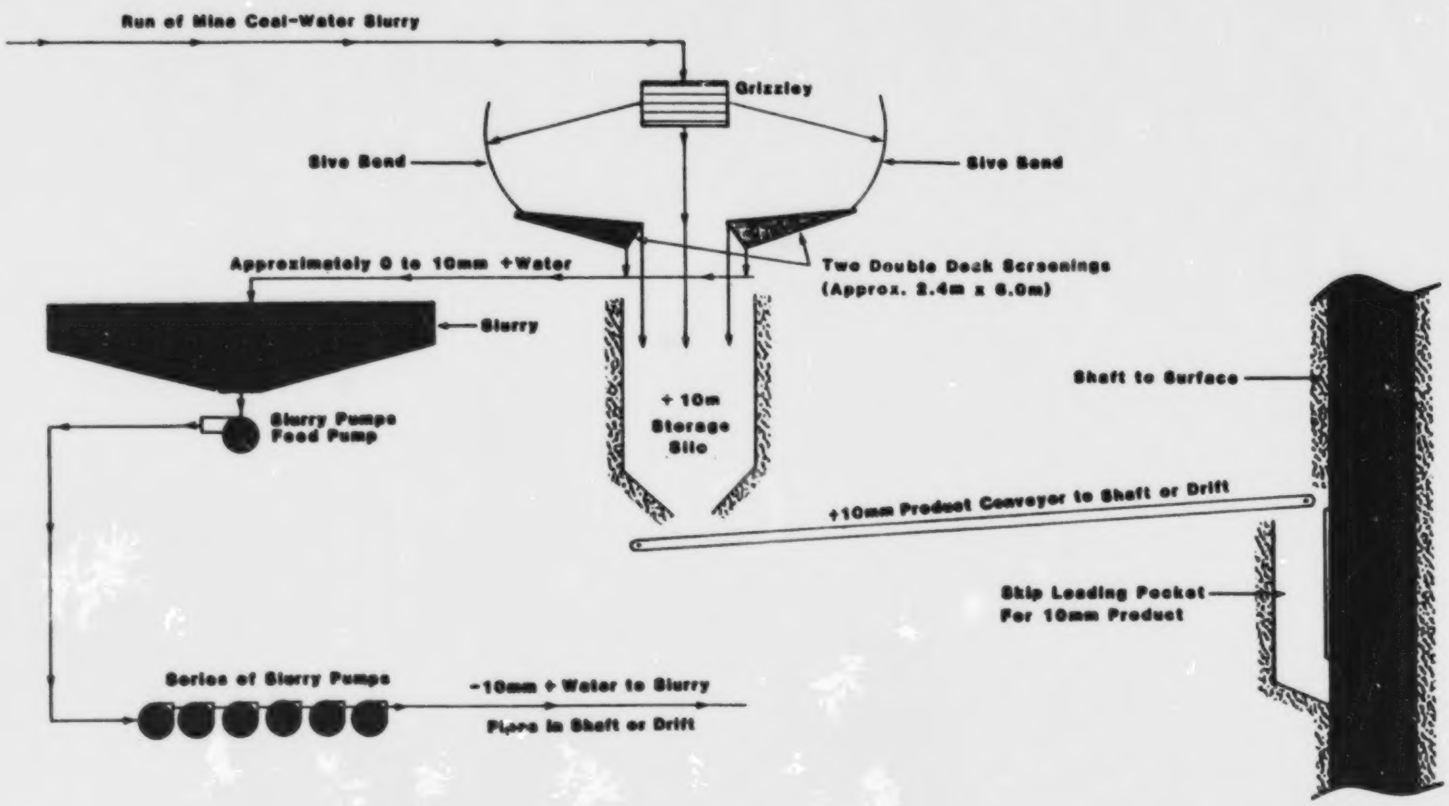


FIG. 3-41 CONCEPTUAL UNDERGROUND SLURRY PUMPING AND CONVEYING COMPLEX GENERAL ARRANGEMENT DRAWING

Hydraulic transportation systems are, by their very nature, relatively dust free, present greatly reduced hazards for methane explosions, fires, and haulage personnel accidents. They take up considerably less room in the roadways than other systems and can be operated at up to 15% lower operating costs than conventional systems. The major problem, however, is the need to keep the slurry pumping station at the lowest part of the mine. This is especially difficult with a mine layout which is continually advancing down the dip.

The amount of development work which is being undertaken by coal producing countries into the hydraulic transportation of coal is indicative of the potential for these systems.

3.7 PNEUMATIC COAL TRANSPORTATION

The principles and advantages of pneumatic pipeline transportation are in some ways comparable to those of hydraulic transportation systems. Although pneumatic stowing has been used to back fill waste rock in European coal mines since the 1930s, pneumatic transportation of coal is still a relatively new development. Small pneumatic hoisting systems have been successfully installed in the UK and USA to increase shaft capacity, but pneumatic transportation has not yet been used to transport coal in and around an underground coal mine.

The typical pneumatic coal transportation system, as applied to shaft hoisting comprises (Fig. 3-42):

(i) A screening chute on the main coal conveyor from which the undersize (-25 mm) is fed by belt conveyor to

(ii) a small roadway bunker of 50 t capacity. Coal is fed from this bunker at a consistent rate by a conveyor, which delivers directly to

(iii) feeder which through a rotary valve feeds the coal into the airstream in the pipeline.

(iv) Rotary blowers provide the air to 100 kN/m^2. Silencers are incorporated in the intake and exhaust sections of the air supply.

(v) Flamehardened alloy steel pipeline through the shaft.

(vi) A cyclone on the surface which recovers the coal from the airstream and reloads it on to the R.O.M. coal conveyor on the surface.

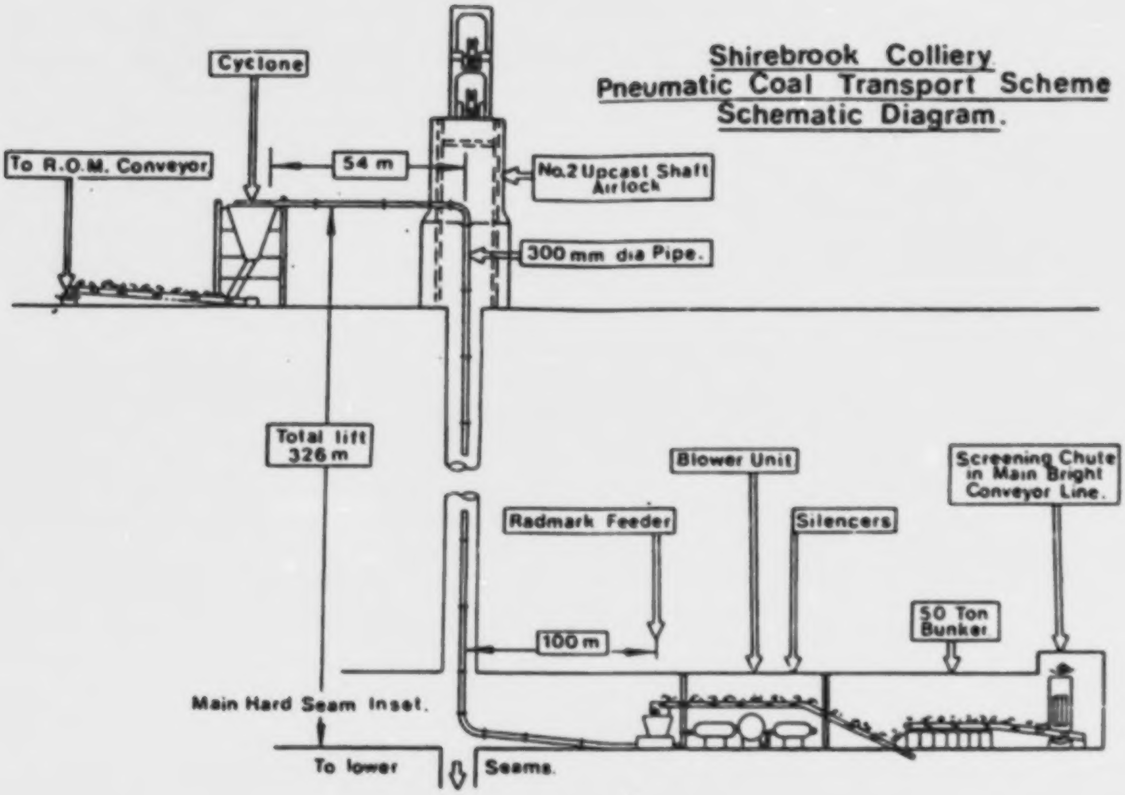


FIGURE 3-42 PNEUMATIC HOISTING SYSTEM

This type of system is being used in the United Kingdom to increase shaft hoisting capacities, by handling the -25 mm fraction. Using a 525 kW blower and 25 kW feeders, capacities of up to 100 t/hr are being achieved through vertical lifts of up to 300 m. The low pressure pneumatic system can handle up to 400 t/hr in the horizontal transportation mode.

3.8 SURGE CAPACITY

Any transportation system has to be designed to handle short duration surges in capacity, such as three times the designed rated capacity. This is achieved in various ways.

In rope and locomotive haulage systems, extra rolling stock is often available which is filled and put into sidings until it is convenient to transport the units on the haulage system.

In conveyor systems, surge capacity is made available through bunkers or silos. These can be of the strata type, where the bunker is excavated in rock, usually in the form of a vertical silo, or the horizontal conveyor type (Fig. 3-43). Capacities range from fifty tonnes to several thousand tonnes dependent on location in secondary or primary transport systems, and the surge capacities to be handled. Roadway and strata bunkers are also used with rope, rail and trackless haulage systems.

In hydraulic systems, surge capacity is provided by using the coal/water slurry sump or sumps which are constructed of a suitable size to accommodate the surge.

3.9 RECENT DEVELOPMENTS

391 NEW DEVELOPMENTS IN ROPE HAULAGES

The major developments in recent years relate to the applications of rope haulages to men and materials transportation, and whilst these systems are outside the scope of this report, they are summarized below:

- radio control
- cyclo - converter drive (variable speed)
- hydraulically operated rope clamps
- captive rail systems
- bogie designed vehicles
- special purpose vehicles and containers

FIGURE 3-43 MOVING BED BUNKER

392 NEW DEVELOPMENTS IN LOCOMOTIVE SYSTEMS

The most recent developments in locomotive systems include:

- adhesion drive
- rack drive
- high capacity batteries
- battery/trolley locomotives
- automatic and remote control
- intrinsically safe electronic engine monitoring
- hydrodynamic powershift transmissions
- new suspension (rubber)
- solid state thyristor control for battery locomotives
- dynamic braking

393 NEW DEVELOPMENTS IN BELT CONVEYORS

The most recent developments in belt conveyor systems include:

- systems for precise control of acceleration and deceleration on start up and stopping

- booster drives

- curved conveyors achieved by banking the structure outwards

- angle stations for abrupt changes of direction

- steel cord belting

- fabric belting incorporating aramides

- computer controlled remote monitoring and control

- variable speed direct drives

- variable filling fluid couplings (computer controlled)

PART 4

PRELIMINARY SYSTEM SELECTION AND DESCRIPTION

PART 4 - PRELIMINARY SYSTEM SELECTION AND DESCRIPTION

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4.1 SYSTEM REQUIREMENTS

The primary requirements (MUSTS) which have to be met by the coal transport systems, for the purposes of this study are:

411 SECONDARY SYSTEMS

(1) Capacities from 350-600 tonnes per hour
(2) Ability to operate on gradients of 25%
(3) Operate over distances from 200 to 2000 metres

412 PRIMARY SYSTEMS (Fig. 4-1)

(1) Capacities from 1400-2400 tonnes per hour
(2) Ability to operate on gradients of 25%
(3) Ability to accept surges three times capacity in (1) for a duration of five minutes
(4) The ability to operate with a maximum lift of 900 metres over a transport length of 10 kilometres
(5) The ability to negotiate a 45 degree horizontal change of direction

4.2 SYSTEM SELECTION

421 SECONDARY SYSTEMS

Although it was not stated in the scope of work for the study, the secondary systems will have to operate over distances which are continually varying, either increasing in the case of longwall advancing mining and room and pillar development, or reducing in the case of longwall retreat mining and room and pillar depillaring. These distances can range from as little as 200 metres to over 2000 metres. The latter distance effectively eliminates the use of trackless mining.

On a capacity basis, all other systems have the ability to transport the tonnages required, however, it would not be practical or economical to consider using cable belts and steel cord belts. This leaves the contending systems as - rope haulage, locomotive haulage, fabric belt conveyors and hydraulic transportation systems (Table 4-1).

When the gradient requirement is taken into consideration, rope and locomotive haulages are eliminated from consideration

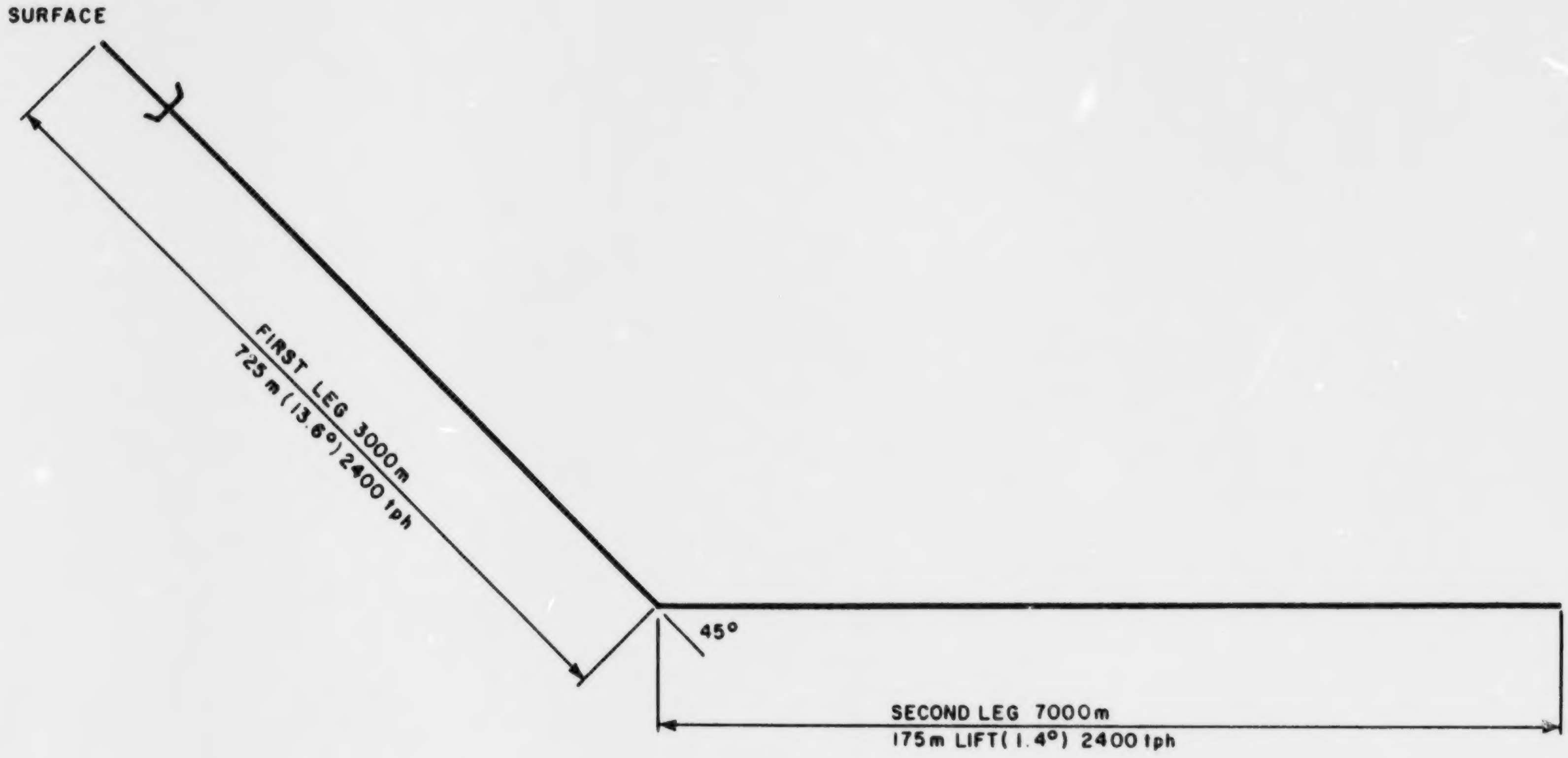


FIGURE 4-1 SCHEMATIC LAYOUT OF PRIMARY TRANSPORT SYSTEM REQUIREMENTS

TABLE 4-1

Secondary System Capabilities (MUSTS)

	Capacity (600 tph)	Gradient (25%)	Distance (max 2 km)
Rail			
- Diesel	Yes	No	Yes
- Battery	Yes	No	Yes
- Trolley Wire	Yes	No	Yes
- Trolley/Battery	Yes	No	Yes
- Compressed Air	Yes	No	Yes
- Rack Drive	Yes	No	Yes
Rope Haulage			
- Direct	No	Yes	Yes
- Endless	No	Yes	Yes
- Main & Tail	No	No	Yes
Conveyors			
- Steel Cord	Yes	Yes	Yes
- Cable Belt	Yes	Yes	Yes
- Booster Drives	Yes	Yes	Yes
- Conventional	Yes	Yes	Yes
Hydraulic			
- Gravity	Yes	Yes(-)/No(+)	Yes
- Slurry Pump	Yes	Yes	Yes
- Air Lift	Yes	Yes	Yes
- Hydrohoist	Yes	Yes	Yes
Pneumatic	No	Yes	Yes
Trackless Vehicles	Yes	No	No

NOTE: (1) Must also be compatible with primary system.
(2) A 'NO' in any category eliminates the system.

(vii)

because rope haulages do not have the tonnage capacity on the 25% gradient, and in the locomotive system, whilst prime movers are available which can operate on the steep gradients, they do not have sufficient power to meet the capacity requirements.

The applicable transport systems are therefore (1) belt conveyors using conventional solid woven fabric belts with or without booster drives and (2) hydraulic gravity or slurry pumping systems.

The final selection of any secondary system will, however, have to be related to the primary or main system, since compatability between primary and secondary systems is essential. For example, it is unlikely that a hydraulic secondary transport system will be used with a belt conveyor primary system.

422 PRIMARY SYSTEMS

The process applied to the selection of the primary transport systems, can be directly related to their ability to meet the four main criteria (capacity, gradient, 45° bend and distance). Table 4-2 summarizes the key factors.

Irrespective of the other limiting criteria, rope haulage, trackless and pneumatic transport systems are not capable of meeting the capacity criteria and are thus not applicable.

Locomotive haulage is more than capable of meeting the capacity needs, but is not able to meet the added gradient requirement, and is thus eliminated.

The systems which are capable of meeting the capacity, gradient and distance requirements are:

1. Belt conveyors using solid woven belting and booster drives.
2. Belt conveyors using steel cord belting.
3. Cable belt conveyors.
4. Slurry pipeline systems.

Each system will also require to have inbuilt surge capacity.

In the following sections of the report, each of the above systems is described in detail covering basic concepts and capacities; operating criteria in relation to the study requirements;

TABLE 4-2

Primary System Capabilities (MUSTS)

	Capacity (2400 tph)	Gradient (25%)	Distance (10 km)	45° Bend
Rail				
- Diesel	Yes	No	Yes	Yes
- Battery	Yes	No	No	Yes
- Trolley Wire	Yes	No	Yes	Yes
- Trolley/Battery	Yes	No	Yes	Yes
- Compressed Air	No	No	No	Yes
- Rack Locomotives	No	No	Yes	Yes
Rope Haulage				
- Direct	No	Yes	No	Yes
- Endless	No	Yes	Yes	Yes
- Main & Tail	No	Yes	No	Yes
Conveyors				
- Steel Cord	Yes	Yes	Yes	Yes
- Cable Belt	Yes	Yes	Yes	Yes
- Booster Drives	Yes	Yes	Yes	Yes
Hydraulic				
- Gravity	No	Yes(-)/No(+)	Yes	Yes
- Slurry Pump	(Yes)	Yes	Yes	Yes
- Air Lift	No	Yes	No	Yes
- Hydrohoist	No	Yes	No	Yes
Pneumatic	No	Yes	No	Yes
Trackless Vehicles	No	No	Yes	Yes

NOTE: A 'NO' in any category eliminates the system.

monitoring and control; safety; costs (where available); advantages and disadvantages; and descriptions of installations.

4.3 CONVENTIONAL FABRIC BELT CONVEYORS INCORPORATING BOOSTER DRIVES

431 BASIC SYSTEM

The booster conveyor drives have been described in Section 353.2. The conventional belt conveyor system, whether it is fabric belt, steel cord belt or cable belt has its drive unit at the head end, applying all the tractive effort at that point, with resulting high belt tensions. The introduction of the booster drive at intermediate points along the length of the conveyor enables belt tensions to be reduced and capacity increased (Fig. 4-2).

The booster drive adds power through friction drive to either the top, bottom or top and bottom belts of the main conveying belt. Booster drives may have single or double drive units, and, theoretically there is no limit to the number of booster drives which can be incorporated into a conveyor system.

There are three basic criteria for the successful operation of booster drives.

(i) The pressure belt or drive belt of the booster conveyor should be narrower than the main belt to maintain directional control and cleanliness between the two driving surfaces.

(ii) The length of belt in contact is dependent on the power to be transmitted. Rule of thumb guidelines are that between 0.8 and 1.5 metres are required per kilowatt of drive power.

(iii) Sequential starting of drive units is necessary to prevent slip. Intermediate drive start up should coincide with the arrival of the tension wave in the belt. The belt tension wave speed V is defined by $V^2 = T/M$, where T = residual tension in belt and M = mass of the belt.

The power which can be introduced into a belt through a driving drum is related to the belt tensions at entry and exit from the drum, the angle of wrap, drum diameter and the coefficient of friction. The power which can be transferred by the booster drive is independent of the tension in the main belt, depending (for a given belt width) only on the coefficient of friction between the two belts and the length of contact.

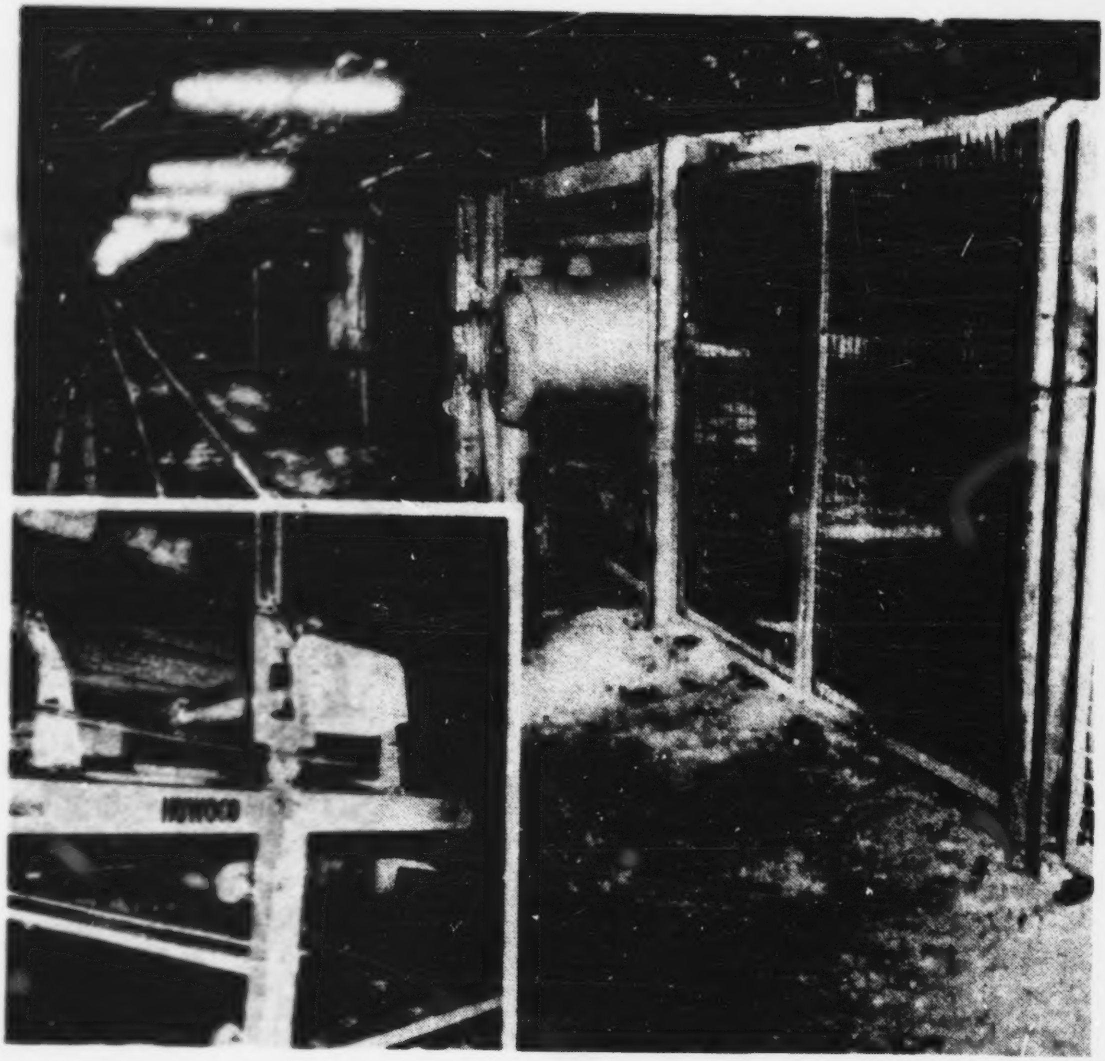


FIGURE 4-2 BOOSTER DRIVE IN EXISTING CONVEYOR

The booster drive design enables the power to be transferred to the underside or clean or non-carrying surface of the main belt.

Prototype testing of the booster drives in West Germany took place on surface conveyors throughout the full range of winter and summer climatic conditions, and included flooding the drive belt interface with water. Results showed that it is possible to design booster drive conveyor systems for any loading and operating conditions, and to determine the optimum drive path length, drive location, and avoid drive belt slip even with gaps in the load on the conveyor belt.

It is now possible to transport coal by belt from the deepest workable measures in drifts to the surface.

432 OPERATING LIMITS

Booster drives have been applied, to date, within the following operating limits.

(i) Drive Unit Power - 90 to 560 kW
(ii) Units per Drive Head - 1 to 3
(iii) No. of Booster Drives in a Conveyor - 1 to 5
(iv) Booster Drive Length - 80 to 300 metres
(v) Belt Speed - 2.0 to 3.1 metres/second
(vi) Belt Length - 500 to 6100 metres
(vii) Vertical Lift - 0 to 350 metres
(viii) Gradient - 0 to 1 in 3 (18°, 33%)
(ix) Capacity - 400 to 2000 tonnes per hour
(x) Belt Width - 910 to 1350 millimetes
(xi) Belt Type - 5 to 15 plus Kevlar

These do not however denote the maximum limits for belt conveyors, but are indicative of the range of conditions in which booster drives have been applied.

Booster drives were initially applied to increasing the capacity of existing conveyor belts, but are also now being used for new capital projects.

System availabilities range from 90% to 99% dependent on the number of drives in the system. The greater the number of drives or the higher the power, the lower the availability becomes. The most frequent problem areas are with drive couplings, tension units and delivery jibs. However, the use of automatic and remote controls, together with computer systems which adjust the system characteristics (speed and rate of loading at points along the conveyor) result in optimization of the system and consequent increase in reliability and availability.

The developments in the use of aramides in the solid woven fabric belt (Kevlar) are enabling belt performances to equal all bar the highest grade of steel cord belting.

Conventional fabric belting is normally limited to a 10:1 safety factor (breaking strength/maximum tension at normal full load motor output), whereas for steel cord belting a factor of 7:1 is used. Based on minimum warp strength, comparable figures for each type are:

Type 15 Fabric - Solid Woven - PVC - 2687 kg/cm
Type 49 Fabric - Solid Woven - Kevlar - 4000 kg/cm
Type ST4000 Steel Cord - 4000 kg/cm
Type ST7000 Steel Cord - 7000 kg/cm

The increase in strength allows a lower safety factor to be considered and together with the booster drive, considerably extends the application of this combination to higher capacity and single flight conveyors.

However the practical operating limits of any conveyor are decided by a combination of many elements including:

- capacity
- gradient
- length
- lift
- available drive power
- available belt type and width
- belt speed

433 SURGE CAPACITY

Any belt conveyor has the ability to handle any variations or surges in its conveying capacity up to its designed maximum rate. Beyond this point, however, even the smallest surge can cause problems such as spillage and damage to belt and idlers. Most surges are of short duration and whilst it is now technically possible to vary the conveyor speed, it is impractical to do this for a short duration peak.

Surge capacity is usually practically and economically provided by some form of bunkerage. This serves two functions, firstly to absorb variations in output from collector systems and enable a consistent feed to be applied to the main conveyor system,

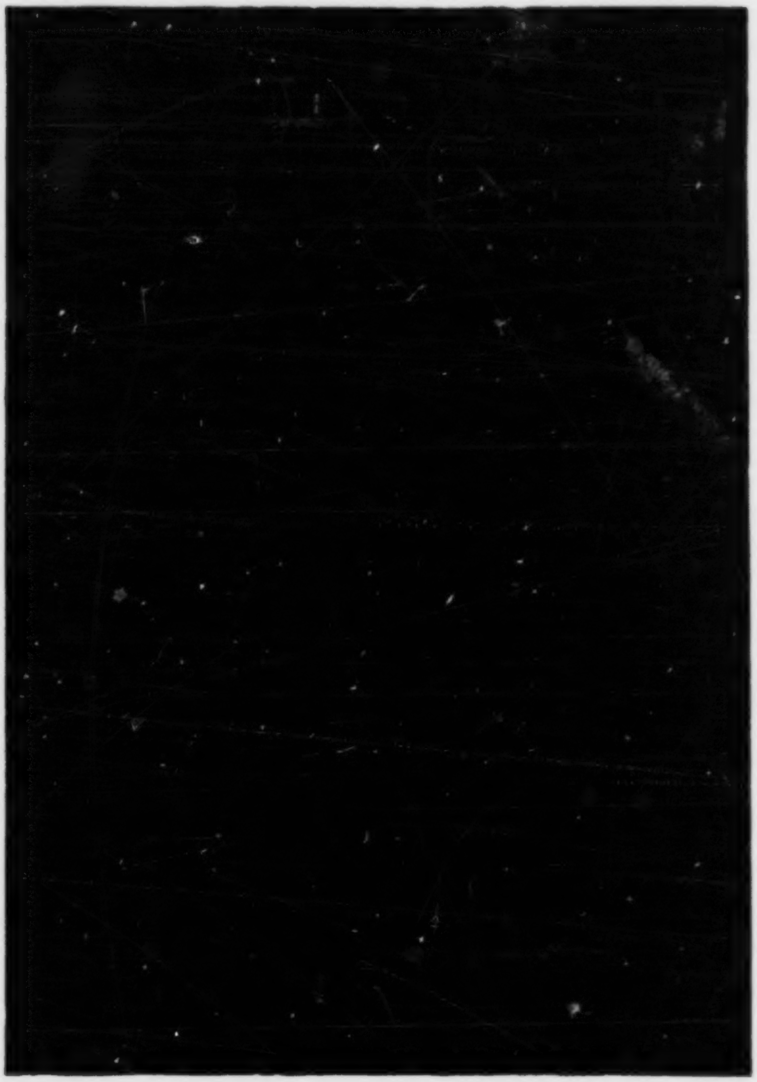


FIGURE 4-3 MOVING BED BUNKER

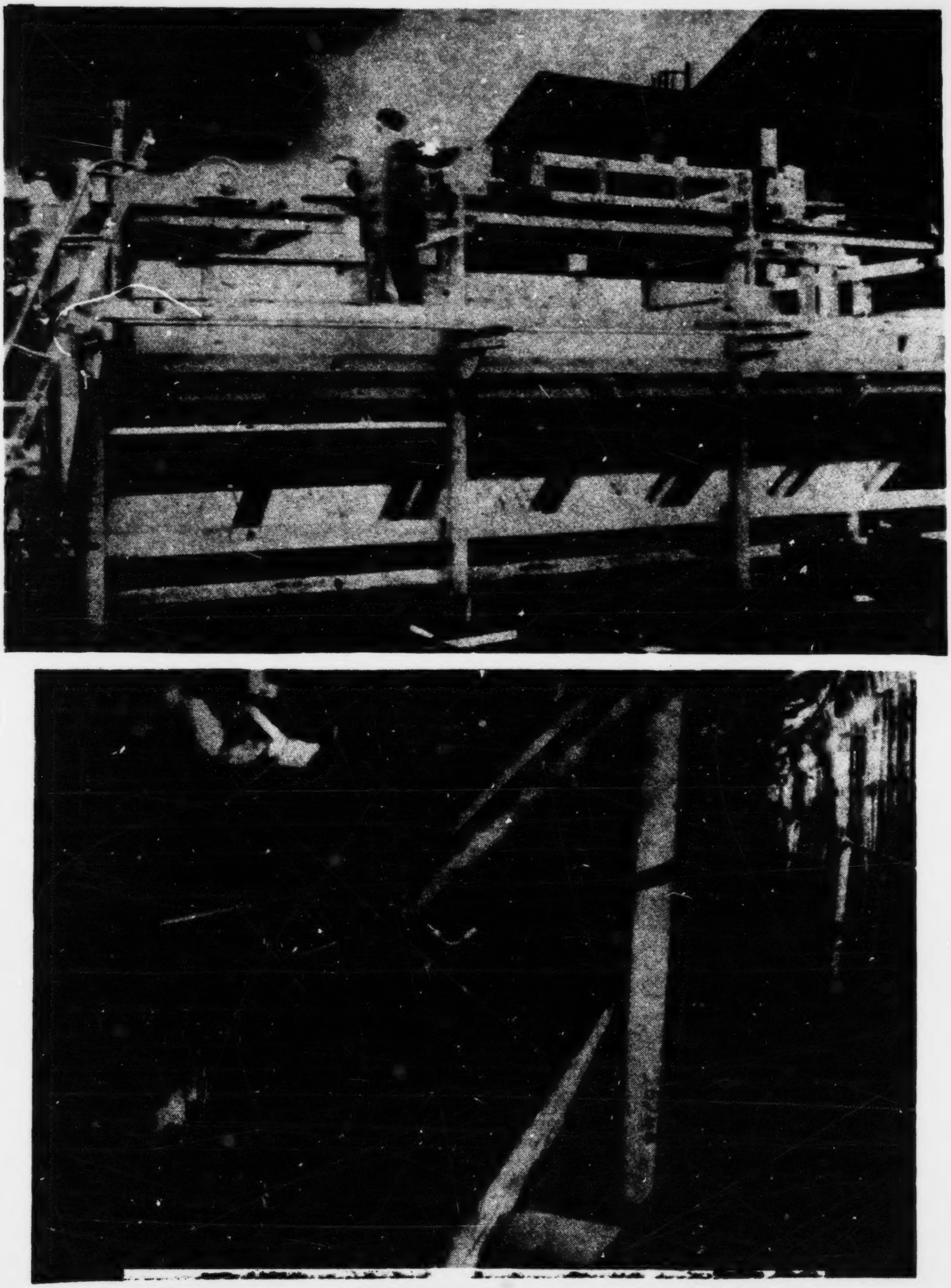


FIGURE 4-4 HORIZONTAL STATIC BUNKER

and secondly, to absorb the effects of small delays and stoppages in the main system outbye the bunker, and thus allow the production units to continue operating. Computer programs have been developed by major mining companies and manufacturers which can simulate operating conditions at a particular mine, identify potential bottlenecks, and thus allow remedial action to be taken.

Storage bunkers or bunker conveyors range in capacity from 30 tonnes to in excess of 1000 tonnes, and are either of the mechanical, roadway or strata type. The mechanical type are usually installed in the mine roadways and consist of either moving bed units with chain conveyors in the base to discharge the mineral, (Fig. 4-3) or hopper discharge units in which the coal is discharged through hopper doors and feeders on to a belt conveyor. (Fig. 4-4).

Roadway bunkers, as the name implies, utilise the actual roadway as the bunker. The coal is discharged into the roadway by plough from the conveyor which is placed at the top of the roadway . Coal is loaded by plough, scraper or gravity onto a chain conveyor situated at floor level.

Strata bunkers are excavated in the rock, usually in the form of shafts or silos. They are preferred to the mechanical type, because although they are more expensive to construct, they are much simpler and cheaper to operate and maintain and have higher capacities.

The required capacity for a bunker is a function of the mine layout, number of producing units, expected rate and duration of peak outputs, expected delays in the outbye system, and the need to bunker and batch control waste rock from development.

Bunkers are often best placed at changes of direction in the transport system, or where several feeds coalesce.

Monitoring is normally applied for feed rate in, temperature, dust, methane, mineral level and feed rate out.

434 MONITORING AND CONTROL

As the capacities and horsepowers of the conveyor increases, so does the complexity of the system and the need to monitor and control operations thus assumes a major role in the optimization of safety and performance.

The increase in the cost of labour, which forms more than sixty per cent of the operational cost of a conveyor system, also makes automation and remote control and indication necessary.

.1 Control

European experience has shown that the use of surface remote control of properly designed conveyor systems has enabled manpower to be cut in half and capacity increased by up to fifty percent due to improved reliability and availability. For example, at the Hans Aden Colliery in Western Germany, the complete conveyor system for the mine from nine longwall production faces and several development headings, including all bunkers and feeders, to the surface coal preparation plant, is operated and monitored by one man from a surface control room. The mine produces 22 000 tpd.

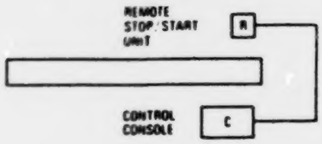
Computerized control (Fig. 4-5) enables the flow of coal to be optimized by controlling conveyors and bunkers against pre-established operating programs. This covers belt start up and stopping, load control, power optimisation when running, feeds from intermediate loading points and batch conveying of coal and waste.

With the booster conveyor system, however, one of the most important requirements is that of speed control and belt starting sequence and timing. As briefly discussed in Section 341, timing of the starting of booster drives is critical. If all drives are started together, 100% slip occurs between the main belt and booster drives. Sequential starting eliminates the problem, reduces stress and wear in the belts, and through the use of such microprocessor's as Dowty's Power Memory Unit, precise control of acceleration (Fig. 4-6) and deceleration (Fig. 4-7) and other transient forces is obtained, thus improving belt life and reducing peak demands on the electrical power system. Fig. 4-8 shows the control circuit schematics.

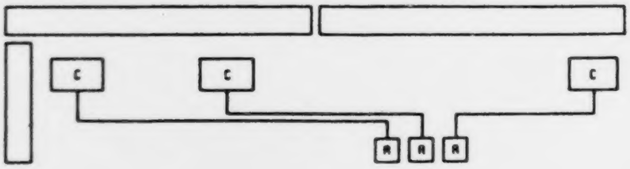
The ability to accurately control the acceleration and deceleration and so limit the tension transients imposed on the belting during these periods affects considerably the safety factor required for the belting. The following figures are typical.

Torque Limitation Acceleration	Belting Factor of Safety Fabric	Steel Cord
170%	8.6	7.3
125%	6.3	5.4
110%	5.6	4.7

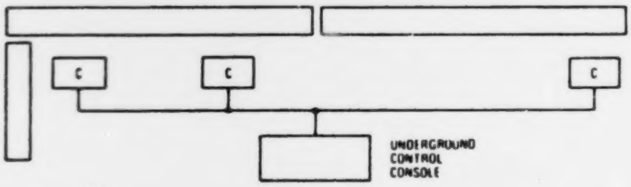
The facility to be able to operate with lower safety factors, and thus lower specification belting can result in significant savings in belt costs especially with the high cost steel cord belting.



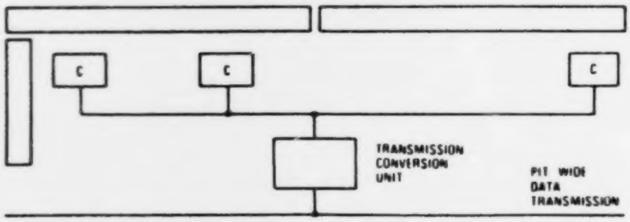
(a) Local control



(b) Remote control using separate cables

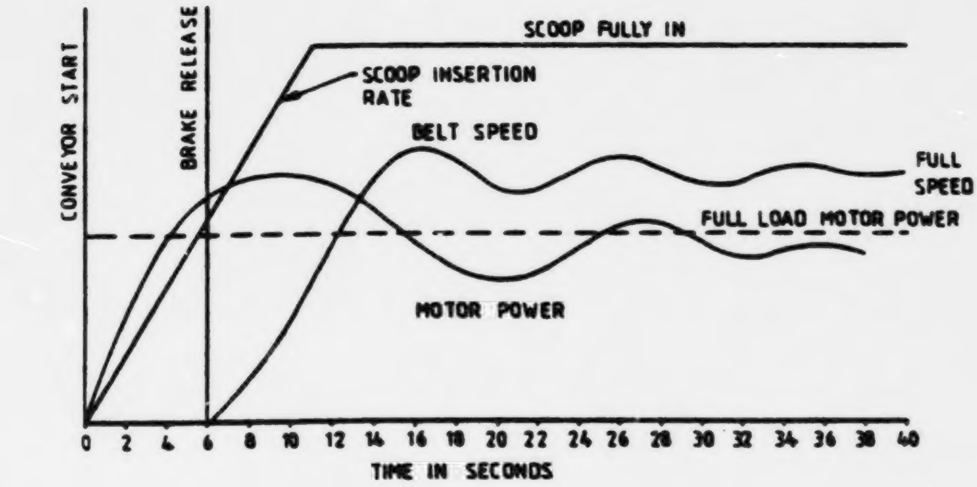


(c) Remote control using short-haul data transmission

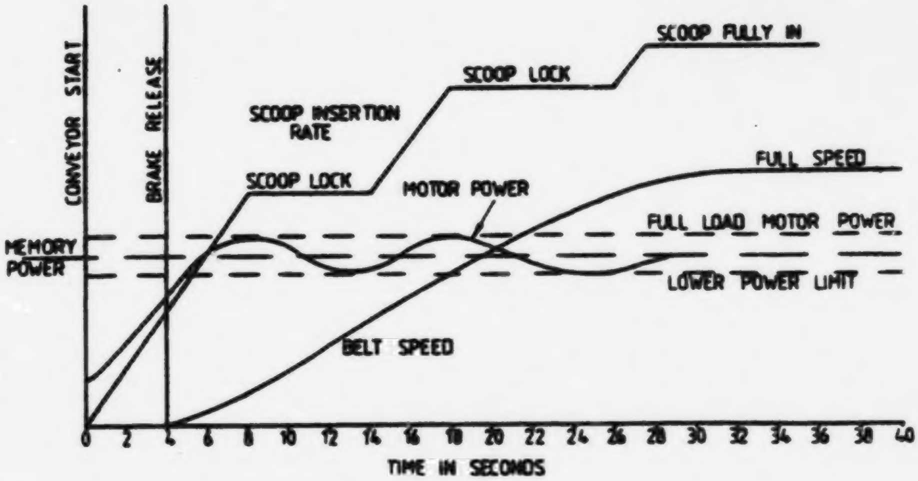


(d) Remote control from surface

FIGURE 4-5 CONVEYOR CONTROL ARRANGEMENTS

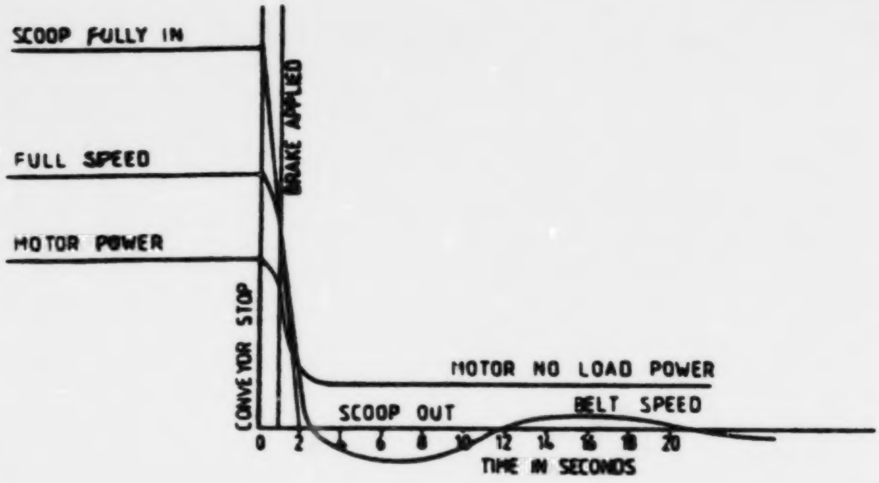


(a) CONVENTIONAL

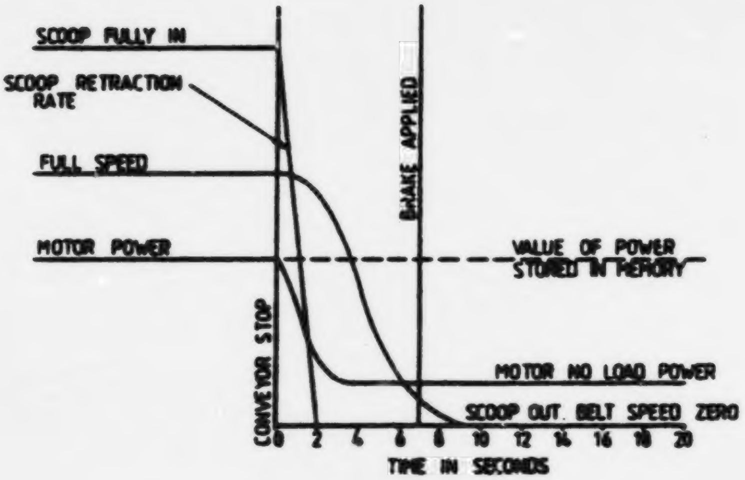


(b) CONTROLLED

FIGURE 4-6 COMPARISON OF CONVEYOR STARTING SPEEDS AND POWER



(a) CONVENTIONAL



(b) CONTROLLED

FIGURE 4-7 COMPARISON OF SPEEDS AND POWERS WHEN CONVEYOR STOPPED

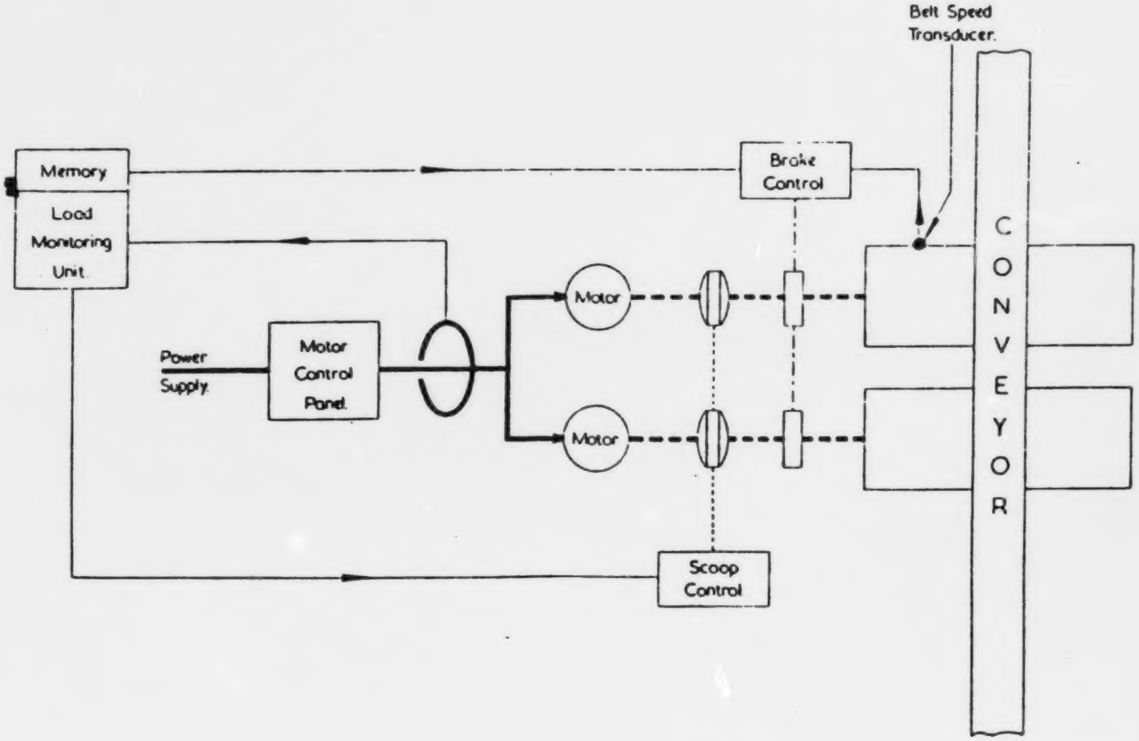


FIGURE 4-8 SCHEMATIC OF PMU TYPE CONTROL SYSTEM

One of the main areas for improvement is the effective automation of transfer points. This requires proper product sizing using lump breakers in the collector systems, good chute design and effective monitoring. The indications from the UK are that the cost of a remotely operated and controlled transfer point was of the order of $32,000 (CDN$ 1980). This expenditure enabled three men to be eliminated at a saving of $42,000.

Many systems are available for the effective control of conveyor systems, of which the best known is the MINOS system developed jointly by the UK NCB and Huwood.

.2 Monitoring

Axiomatic to any control system is the requirement to monitor the health, safety and operation of the system. Monitoring is essentially covered by three aspects:

- operational monitoring
- condition monitoring
- general monitoring

Operationl monitoring is concerned with such aspects as: belt speed, belt slip, belt sequence, torn belt, blocked chute, etc.

Condition monitoring covers temperature and fluid levels in equipment.

General monitoring covers communication and signals.

Booster conveyor systems present a greater requirement for both monitoring and control due to the increase in the number of drive units and associated components in the systems.

435 SAFETY

Safety has to be considered from two aspects - the risk of accidents to personnel and the risk of a hazardous incident due to equipment malfunction or failure.

.1 Personnel

Discounting for the purposes of this study accidents due to manriding on conveyors, the bulk of the personnel accidents associated with conveyors occur at the ends of the system, i.e. at the drivehead, tension, jib and transfer points. These are mostly to maintenance and conveyor attendants, resulting from getting involved with driving or return drums whilst they are in motion, or whilst crossing moving belts.

In the UK mines, over the ten years from 1972 to 1981 (latest figures available), fatalities on conveyor installation represented 9% of all fatalities related to underground transport operations (compared with 22% for locomotives and 53% for rope haulages). In the non-fatal accidents, the respective figures were 15%, 13% and 53%.

The bulk of all accidents (60%) are due to failure of personnel to adopt recognised good practice.

Consideration of the booster conveyor systems would suggest a potential for improvement in the accident rate due to the elimination of transfer points and lower tensions in belts, but conversely a potential for an increase in the accident rate due to the presence of a greater number of moving parts in the system.

There is insufficient data available to determine which has the greater effect.

.2 Incidents

In spite of the improvements in the fire resistance of conveyor belting, and the exclusive use of such belting underground, underground belt conveyor systems still constitute a continuous potential fire hazard. The greatest danger now arises from collapsed or defective rollers which ignite grease or coal dust in their vicinity (20% of reported underground fires in the UK in 1982 were from this cause). Other potential hazards arise from rubbing belts, brakes, defective bearings, loss of fluids from couplings and gearboxes. Thermal monitoring devices are helping to eliminate the latter causes, whilst sprag clutches and belt alignment switches protect from the former.

The latest development in reducing the fire hazard in conveyor roadways include the water blanket spray which sprays water over the length of the affected area, and the use of infrared and computer technology to scan roadways for hot spots, including the ability to pinpoint the exact location of the source.

The additional drive units involved in the booster conveyor system appear to increase the potential safety hazard with that system since there are more moving parts, however, with the need for remote or automatic controls for efficient starting, and the usual concurrent existence of monitoring systems, it is generally agreed that the system should be safer.

436 COSTS

.1 Capital Costs

Costs are very difficult to compare since they are extremely site or installation specific.

For high capacity systems, study comparisons between locomotive and conveyor haulage for a mine working 2 1/2 shifts per day and producing 8000 t/shift indicate that for capital costs:

(a) over distances of up to 1500 m, conveyors are cheaper
(b) at 7500 m, costs are similar
(c) at 10,000 m, locomotives are cheaper

This arises because the costs for extending the system are cheaper for the locomotive method.

In a comparison of capital costs between the booster conveyor and the steel cord conveyor systems, the following examples indicate the advantages of the booster conveyor system.

(a) Capacity Increase of Existing Conveyors

There was a need to increase the capacity of an existing drift conveyor from 500 t/hr to 1000 t/hr. The original conveyor parameters were:

length - 690 m
lift - 115 m
belt width - 1067 mm
belt speed - 2.54 m/sec
belt type - 8 (solid woven)
horsepower - 287 kW

The capacity increase was accomplished by raising the belt speed to 3.05 m/sec and adding a 224 kW booster drive.

If a single drive head had been used instead, this would have required a new unit of 530 kW with new Type 12 solid woven belt. The comparable costs were:

	Booster	New Drive
Mechanicals	139,160	459,200
Electrics	64,400	137,760
Belting	-	194,640
	$203,560	$791,600

(1980 pounds sterling converted to 1980 Canadian Dollars)

(b) A New Installation - Booster vs. Steel Cord

A comparison was made of the capital costs of installing either a single head end drive steel cord belt conveyor, or a head end drive plus booster drive fabric belt conveyor, in a 1.75 km long drift rising 214 m handling ultimately 900 t/hr with a belt width of 1050 mm and speed of 2.6 m/sec. The comparative capital costs for the 900 kW systems were:

	Booster and Solid Woven Belt (3 x 300 kW)	Steel Cord Belt (1 x 900 kW)
Mechanicals	654,200	627,200
Electrics	129,800	90,700
Belting	257,200	781,600
	$1,041,200	$1,509,500

(1982 pounds sterling converted to 1982 Canadian Dollars)

It can thus be seen that the capital costs are considerably lower for the booster drive systems, especially when used to increase the capacity or length of existing systems.

.2 Operating Costs

Operating cost data is virtually impossible to obtain, however, because of the potential which exists in the conveyor systems for automation, and remote monitoring and control, we would expect operating costs in 'modern' systems to become lower. Experience in the UK, where most of the latest conveying techniques have been introduced, indicates that as the capital cost and complexity (control and automation) increases, so does the cost per tonne conveyed decrease. However, the optimization of the operating costs depends on the reliability factor of each component.

437 ADVANTAGES OF THE BOOSTER DRIVE SYSTEM

The following advantages are claimed for the booster drive conveyor system.

- Reduces the need for large excavations underground to accommodate high horsepower drive units. Booster drives are lighter and easier to transport and install in the mine, occupying smaller areas (64%) and being of less width (54%). Installation interferes less with existing operations.

- Can use belting already in use in existing operations, with considerable cost savings (57%). Special or new type belting not required.

- The booster drive can be added in almost any position in a conveyor, and in any number.

- Can be used to increase capacity of, or lengthen, existing belts, or to enable new installations to use lower specification belting. Single flight conveyors of any length are theoretically possible.

- Enables lower belt tensions to be used, hence lower belt grades, lower weight and power, and improved belt life.

- Eliminates transfer points reducing degradation, dust, and manpower, and simplifies manriding.

- Permits cost savings on capital costs (to 300%) on drives and belting, and on excavation costs underground.

- Standardization of spares reduces replacement costs and time and leads to lower operating costs.

- With the development of the Kevlar 49 belting, the system can approach the capabilities of the steel cord belt with lower capital costs.

- Can continue to operate at reduced capacity if one drive unit fails.

- Transmission of power does not disturb the material being carried on the belt.

- Systems are operating successfully in inclement surface winter conditions.

- Greater reliability due to lower belt tensions, and very low corrosion risks in belting.

438 DISADVANTAGES OF BOOSTER DRIVE SYSTEMS

The following disadvantages of the booster drive conveyor systems have been identified.

- The use of multiple drive units dispersed over long distances leads to control problems for correct sequencing for starting and stopping the belt, and for load sharing between drive units.

- Electrical systems requirements for switchgear, monitoring, control and cabling equipment are greater because of multiple unit needs.
- Multiple drive units require more mining, civil, mechanical and electrical installation work and manhours.
- Drive units are required underground.
- Belt life less than Steel Cord Belting (2:1)
- Lower splicing efficiency (70-80%), including Kevlar belting. This results in need for higher safety factors.
- Possible drive transfer problems in wet conditions or if drive belt surface contaminated.
- Belt slip represents potential fire hazard.
- Complicated to provide variable belt speed facility.
- Not applicable to low tonnage or short belts.
- Installation in existing conveyors may disrupt other services (men and materials) which must use same roadway.

439 WORLD USAGE

It has not been possible to determine how many booster drives are in use in the world. However, booster conveyor drives are in use in U.K., W. Germany, Canada, U.S.A., Australia, Spain, France, Turkey and S. Africa.

In the U.K. coal mines, there were more than sixty in use in 1983.

4.4 STEEL CORD BELT CONVEYORS

441 BASIC SYSTEM

The steel cord belt conveyor uses conventional systems but at much higher cost and belt tensions than is normally the case with the more conventional fabric belt conveyors (Fig. 4-9). The steel cord belt with, as its name implies, steel cords incorporated in the structure of the belt to give it greater strength, enables much higher horsepowers and hence either higher tonnages or longer

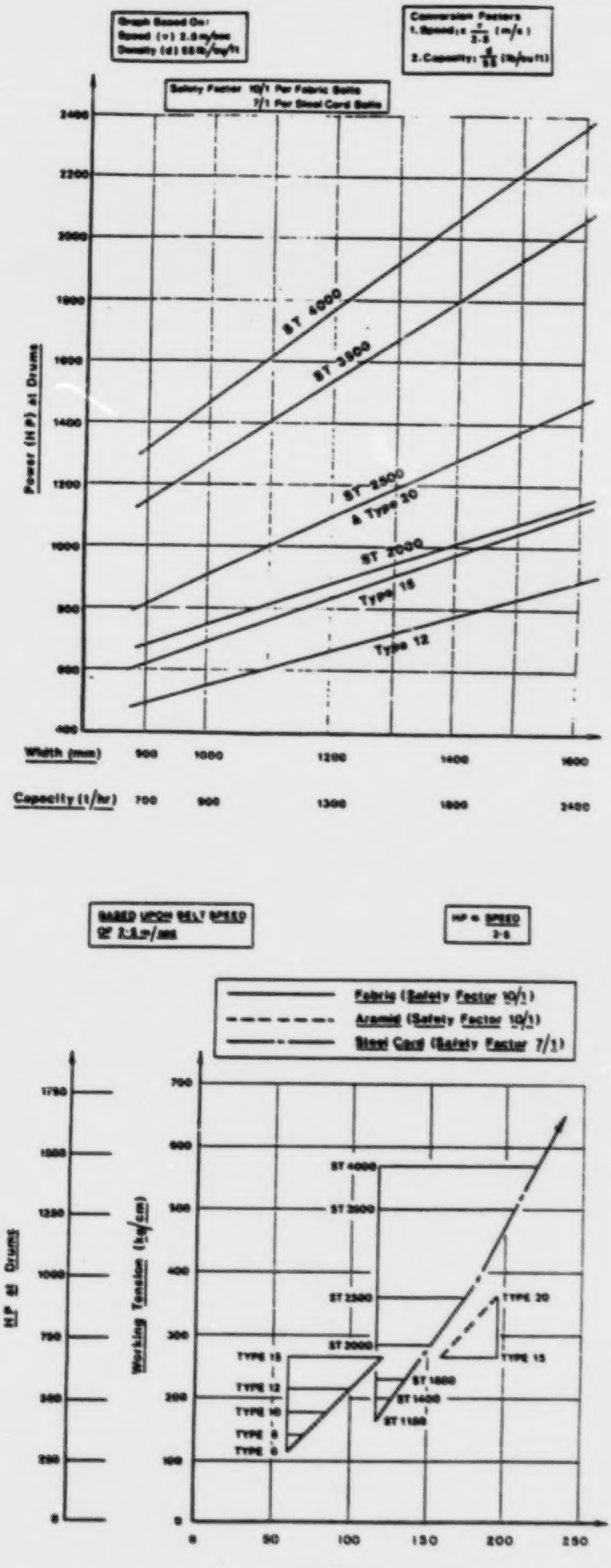


FIGURE 4-9 COMPARISON OF STRENGTHS AND COSTS OF FABRIC AND STEEL CORD BELT

conveyors or greater lifts to be obtained with this system. Perhaps the biggest single feature of the steel cord conveyor system is that in most cases particularly for surface to underground drifts, it allows the drive unit to be placed on the surface in a properly constructed drive house.

The drive unit usually comprises one or two driven drums so arranged that they drive on the clean side of the belt. These drums are normally driven through speed reducers and fluid couplings by squirrel cage motors but at the recent installation at the Selby Mine in the United Kingdom, the drive has been effected by using two winder or hoist motors directly coupled to the drive pulley shaft. In this particular instance the use of hoist motors has also enabled a variable speed facility to be incorporated into the conveyor design.

Because of the inherent strength of the steel cord belt, the steel cord conveyor has its greatest application to the conveying of coal to the surface in slopes or drifts from underground workings. The steel cord belt itself is considerably more expensive than other forms of belt and this taken with a minimum operating width of approximately 900 mm has limited its application to main belt systems where advantage can be taken of its high capacity.

442 OPERATING LIMITS

Steel cord belt conveyors have been applied to date within the following operating limits:

1. Drive unit power 450 - 10,100 kW
2. Number of drives per drive head 1 - 2
3. Number of drives in conveyor system-normally 1
4. Belt speed from 1.7 to 8.4 m/sec.
5. Conveyor length 400 m to 15,000 m
6. Vertical lift from 0 - 1,000 m
7. Gradient 0 - 1 in 4 (14°, 25%)
8. Capacity from 400 tph to 3,200 tph
9. Belt width from 915 mm to 1,350 mm
10. Belt type from ST 2250 to ST 7000

These do not of course denote the maximum limits for steel cord belt conveyors but are indicative of the range of conditions in which they have been applied. As mentioned previously, their prime application for underground coal mines is that of high horsepower single drive single flight conveyors for the main systems for coal clearance for surface drift mines.

Experience to date with steel cord conveyors indicates that their availabilities range from 96 - 99% which partly results from having a single drive unit and also from the fact that the joint efficiencies are of the order of 100%. There are thus no weak spots in the length of the conveyor. The normal safety factor for steel cord belting is of the order of 7 to 1 but if automatic control is used to control the starting and stopping of the conveyor this factor may be reduced to 6 to 1.

With the modern form of steel cord belting which uses more steel cables of a smaller diameter to obtain the same strength, a more flexible belt is obtained and this enables smaller diameter driving drums to be used and hence smaller drives and ancilliary equipment.

The steel cord belt is heavier than other forms of belt and for this reason requires higher horsepcwers to operate similar capacity systems. This, for example, is evident at the Selby Mine where two identical conveyors one steel cord belt and one cable belt are installed in slopes at the mine. For the same tonnage rating, length and vertical lift the power requirements of the cable belt are 8,750 kW whilst those of the steel cord belt are 10,100 kW. In practice it has been found that steel cord belts take approximately twice as much power to run empty, thus accounting largely for the need for higher drive powers compared with cable belts.

443 SURGE CAPACITY

This subject has already been dealt with in Section 3.8 and Section 433. The surge capacity in the steel cord conveyor systems is normally attained through the use of bunkers. However in certain circumstances, this can be marginally attained by variable speed control of the drive motors at least until the point when the maximum carrying capacity of the conveyor is reached. With the high capacity systems in which the steel cord belt is normally used, larger capacity bunkers have to be provided in order to extend the same degree of time coverage as is made available to other conveyor systems. Such surge capacity would almost always have to be some form of strata or roadway bunkers in order to have a sufficient holding capacity.

444 MONITORING AND CONTROL

The requirement to monitor and control steel cord conveyor systems are basically no different to any other conveyor system. The requirements of the steel cord belt conveyor system only differ in that there is only one drive unit to monitor compared with the booster conveyor systems or even the multiple conveyor fabric belt conveyor system.

445 SAFETY

Steel cord belt conveyors have along with cable belt conveyors a distinct advantage over conventional fabric belt conveyors (with or without booster systems), in that there is usually only one drive unit to operate the conveyor and this unit is quite often located on the surface. This removes the potential hazards of heat dissipation and the need for large excavations underground with their consequent problems of stability and support. Systems also have fewer points to monitor and thus fewer pieces of equipment which can become potential hazards. Non-flameproof electrical equipment can also be used if the drive is on the surface.

446 COSTS

.1 Capital Costs

Although the comparison of capital costs for different types of conveyor is difficult because they generally vary according to the site specific conditions, a comparison was made for one mine in the United Kingdom of the capital costs for installing fabric belt, cable belt and steel belt conveyors. This comparison showed that if an index of 1.0 was set for the fabric belt then the relative costs were 1.2 for the cable belt and 1.35 for the steel cord belt. The latter increase was primarily due to the cost of the belting.

.2 Operating Costs

The same study indicated that the anticipated maintenance and running costs over a twenty year period would be, on the basis of the index for the cable belt being 1.0, 1.04 for the steel cord belt and 1.06 for the fabric belt. This took into account the fact that the power requirements for the steel cord belt are at least 15% higher than for cable belts due to the heavier belt and the additional friction losses, that the fabric belt has a much lower life than the steel cord or cable belt, and that the cables on the cable belt need changing every two to three years.

447 ADVANTAGES OF STEEL CORD CONVEYORS

The following advantages are claimed for the steel cord belt conveyor system:

1. All drive and control equipment is in one place.
2. There is no problem with sequence starting as there would be with a series of conveyors or with a booster conveyor system.
3. All conveyor belting is installed and spliced on the surface thus avoiding the problems associated with handling and vulcanising heavy belting underground.
4. With drive and controls on the surface there is no need for flame proof equipment.
5. There is no need for high voltage underground cabling for intermediate drives.
6. Dissipation of heat generated by the drive unit presents no problem for surface drive installations but cause a serious problem in the underground environment.
7. The high joint efficiency and strength of the belt gives much greater life and availability for the steel cord belt.
8. The use of high tensile belt of a strength three times that of standard fabric belt enables single flight single drive conveyors to be utilized for high capacity or high lift applications.
9. Safety factors are much lower than with fabric belts and joint efficiencies are much higher.
10. The steel cord belt is easy to splice and once correctly made requires little attention during the life of the belt. Belt cleaners have little detrimental effect upon the splices.
11. The steel cord belt has a much lower percentage elongation than fabric belt therefore requiring much less belt take-up, also easing starting problems. Belt stretch is of the order of 0.3% which is about one-tenth of that which would be expected with a solid woven belt.
12. The belt is extremely flexible in the transverse plane and therefore gives good belt tracking characteristics and carrying capacity.

448 DISADVANTAGES OF STEEL CORD CONVEYORS

The following disadvantages of steel cord conveyors have been identified:

1. The capital costs of steel cord belt conveyor systems are considerably higher than those for either cable belt or fabric belt systems.
2. The belting is more expensive and therefore if damaged is more costly to replace. It is prone to longitudinal splitting.
3. The power consumed by steel cord belting in both the empty and loaded state is greater due to the greater weight of the belt.
4. Where, due to changes of direction or other considerations, a steel cord conveyor has to be installed underground considerable excavation is required to house the drive unit.
5. Changes of direction cannot be accommodated by angle station and because of the relative lack of flexibility of the belt longitudinally, they are more difficult to obtain through the gradual curving of the conveyor.
6. Any cuts in the belt cover could lead to problems of corrosion of the steel cords within the belt structure particularly when operating in wet conditions.
7. The system is not applicable to low tonnage or short length belts.

449 TYPICAL STEEL CORD BELT INSTALLATIONS

.1 STEEL CORD BELT CONVEYOR, SELBY COALFIELD (FIG. 4-10)

(a) Introduction

An exploration program in 1960 conducted by the National Coal Board established a very large coalfield indicating total reserves of 2000 million tonnes with 600 million tonnes in the Barnsley Seam alone. The Barnsley Seam is 300 m deep at the western edge of the coalfield and dips north-easterly to a depth of 1100 m deep.

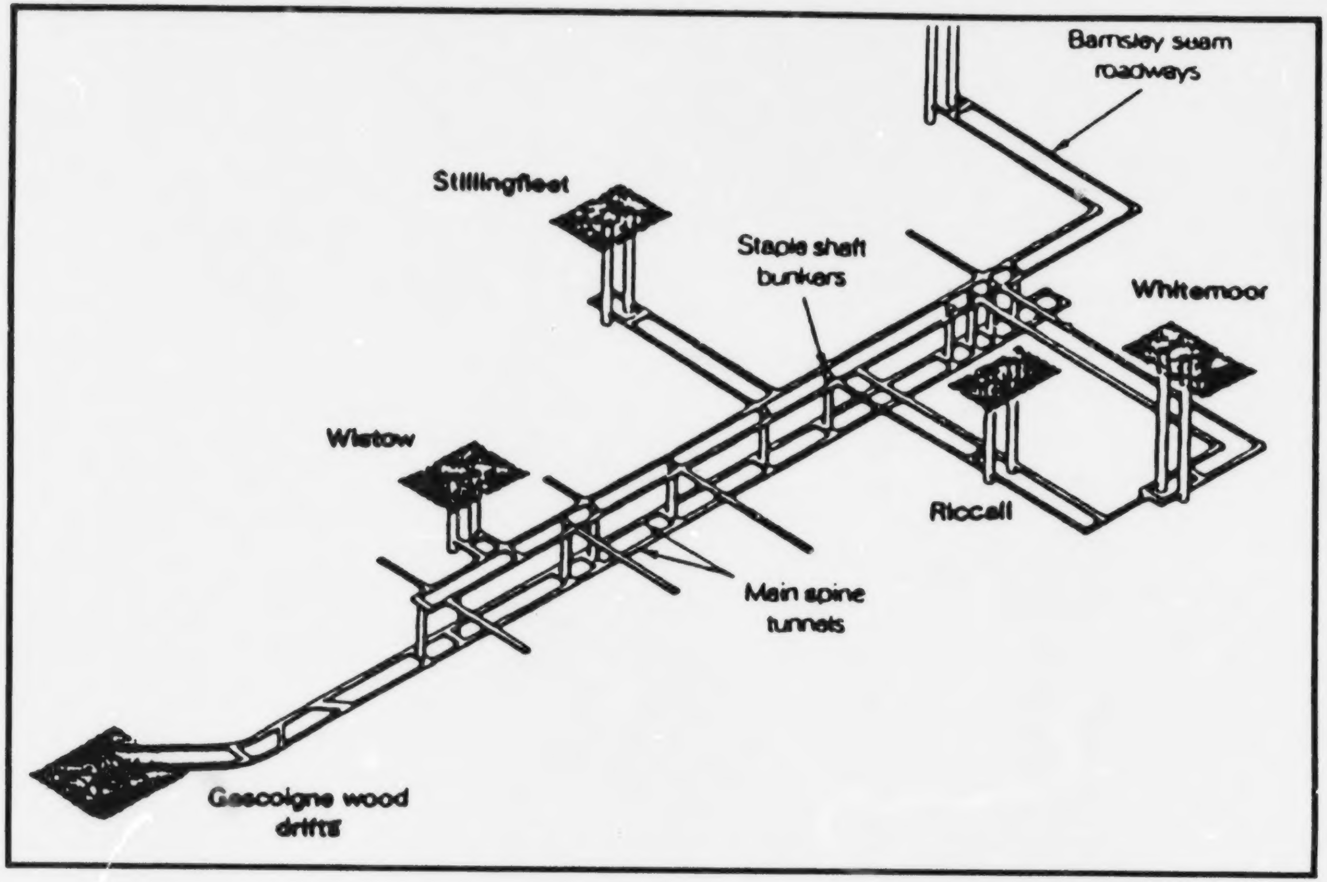


FIGURE 4-10 SCHEMATIC SHOWING SELBY MINE AND MAIN 15KM SPINE ROADS

The objective of this coal field was to produce 10 million tonnes of coal per year; but because of lack of rail connections and poor communications plus the impact of agriculture life in the area it was impractical to construct five self-contained mines, each capable of producing two million tonnes per year.

To obtain the ten million tonnes per year it was decided to exploit the Barnsley Seam alone as clean coal could be produced without the need of a coal preparation plant. In addition it was decided that the coal would be brought to the surface at one point by two main spine tunnels. Five satellite mine sites built within the coalfield are designed to provide man access, materials handling and ventilation to the workings. Each of the mines has separate management.

To remove the coal the main spine tunnels will be driven 15 kilometres across the coalfield. The tunnels are 70 m apart and dip at a gradient of 1 in 4 through the upper strata and then the line of the tunnels will be approximately 70 m below the Barsley Seam. Vertical strata bunkers will be used to store coal before it is transported to surface along the spine roadway conveyors.

(b) Conveyor Concept

As two conveyors would be required to convey the coal from the mine working, two separate conveyor design concepts were employed: in one tunnel a cable belt conveyor would be installed, the other a steel cord belt conveyor.

The following describes the aspects of the steel cord conveyor belt. In designing the steel cord belt certain criteria had to be met.

- sufficient capacity to deal with all material produced by the five mines
- complete duplication so that 10 million tonnes per year could be handled by each conveyor
- facilities to enable the conveyor to handle coal and stone separately
- accept feed from eleven separate stations along the total length of the conveyor
- to be fully automatically controlled with capabilities of stopping, starting, loading, discharging and measuring loading rates, capacities, power consumption, etc.

- to be a single flight conveyor with a single drive on the surface

- to be capable of being extended as spine roadways are developed and to handle coal/stone from the working mines and stone from developing spine roadways

- keep temperatures of the spine roadways and drifts to a minimum

In selecting the single flight conveyor concept with the drive on surface the majority of the criteria was established.

(c) Technical Features of the Conveyor

The main technical features of the conveyors are discussed in more detail. The carrying capacity of this system is 1828 tph from the tail end, up to 3250 tph outage of bunker No. 1.

(i) The Drive

The main drive comprises a single integral machine forging combined drum and shaft. The drum is 2.67 m diameter and the shaft is 1.6 m in diameter, and together they weigh 90 t. The total weight with roller bearing and anti run-back clutches is 125 t. Each drive shaft is directly coupled to overhung armatures of two 'E' type NCB, thyristor controlled dc winder motors. The motors are 5050 kW 60 rpm winder motors. The design was simplified by making the conveyor drum integral with the drive shaft. The motors can operate at speeds from zero to 60 rpm: Inspection speeds zero to 2.5 m/sec, conveying 2.5 to 8.4 m/sec. Each motor armature runs off its own loop control with fields in series in normal operation. Both motor armatures connected in series and supplied from one armature converter system only, will give maximum torque at half speed operation

(ii) The Tail End

The tail end unit consists of 1000 mm diameter pulleys built into a unit which travels along continuous beams. The unit is self powered hydraulically and advances using "slipper grippers" acting on the continuous beams.

(iii) The Tensioning Arrangements

The belt tension equipment is located on the surface. The equipment comprises of a 150 t gravity weight to ensure the slack belt is taken up during start-up, a constant torque tensioning device that maintains running tension under all conditions of loading and a locking device to lock-in the belt stretch on stopping. This lock-in feature ensures the belt tension is retained so that on restarting, the current demand is kept to a low level assisted by the extended acceleration time provided by the dc motors.

(iv) Line Stands

The idler sets are three roll 30° troughed carrying idlers (168 mm diameter) with two semi troughed return idlers. The idlers are heavy duty and designed for the maximum speed of the conveyor. Both top and bottom sets of idlers are individually aligned and skimmed; and by the use of optical alignment settings, the profile of the conveyor can be maintained to a high standard.

(v) Conveyor Belting

The steel cord belt is 1300 mm wide by 28.3 mm thick. It has 57 steel cords each 13.[illegible] mm in diameter at 22.25 mm pitch. The factor of safety is 5:1 and is graded ST 7100 (7100 kg/cm). Each belt length is 440 m long and weighs 40 tonnes.

(vi) Discharge Arrangements and Drive House Design

The discharge hopper acts as a transfer chute from the head pulley to two collecting conveyors below the drive house. The hopper is carried on load cells and has a capacity of 80 t and must contain all the coal discharged from the conveyor without stopping when the routing of the coal is changed on the ROM plant.

(vii) Belt Cleaning

To ensure the belt is cleaned perfectly to enable vibration free condition for rollers, bearings, etc., belt washing has been incorporated. Plus 1/2 mm material is removed by a single piano wire scraper plus a raclar multi wire scraper. The removed material is delivered into a twin scrolled fines box which then discharges into the main discharge chute. Within an enclosed launder, three lines of high pressure nozzles direct water onto the belt. A primary rotating dewatering scraper then scrapes off excess water followed by a bank of suction nozzles which draw off the remaining water. All effluent is collected into a settling tank. Clean water is drawn off and run to waste while the solids are disposed of by tanker.

.2 GRIMETHORPE SURFACE DRIFT CONVEYORS (FIG. 4-11)

The Barnsley Area of the National Coal Board is spending a massive $600 M to create a new coal field from old. The investment will complete a revolutionary programme to concentrate almost all the 150 year old area output currently running at 8.5 m tonnes per year from seventeen Collieries, at three major coal handling points.

Most of the mines in each of the three complexes will be linked underground by a network of new roads. The major project will increase overall productivity by nearly one tonne to 3.54 tonnes per man shift, compared to the present U.K. national average of 2.48 tonnes per man shift.

This project will be completed in 1985, when nearly 9 million tonnes of coal per year will be conveyed up three giant drifts, surfacing at Woolley, Grimethorpe and South Kirkby Collieries. At each of these three key nerve centres, coal belts will feed into new generation central washeries, capable of preparing coal for steel making, power stations or the expanding industrial market.

Grimethorpe Colliery, near Barnsley, was sunk in 1894. There are three shafts and coal is wound from fully mechanised coal faces, producing 1,247,000 tonnes of coal for the Newhill, Fenton and Parkgate seams. Work is now in progress on a project to concentrate the output from Grimethorpe, Barrow, Darfield and Houghton Collieries by connecting mines through underground conveyors to a surface drift and a central coal preparation and disposal plant on the Grimethorpe surface. This project is referred to as the 'Barnsley Area South Side Project'.

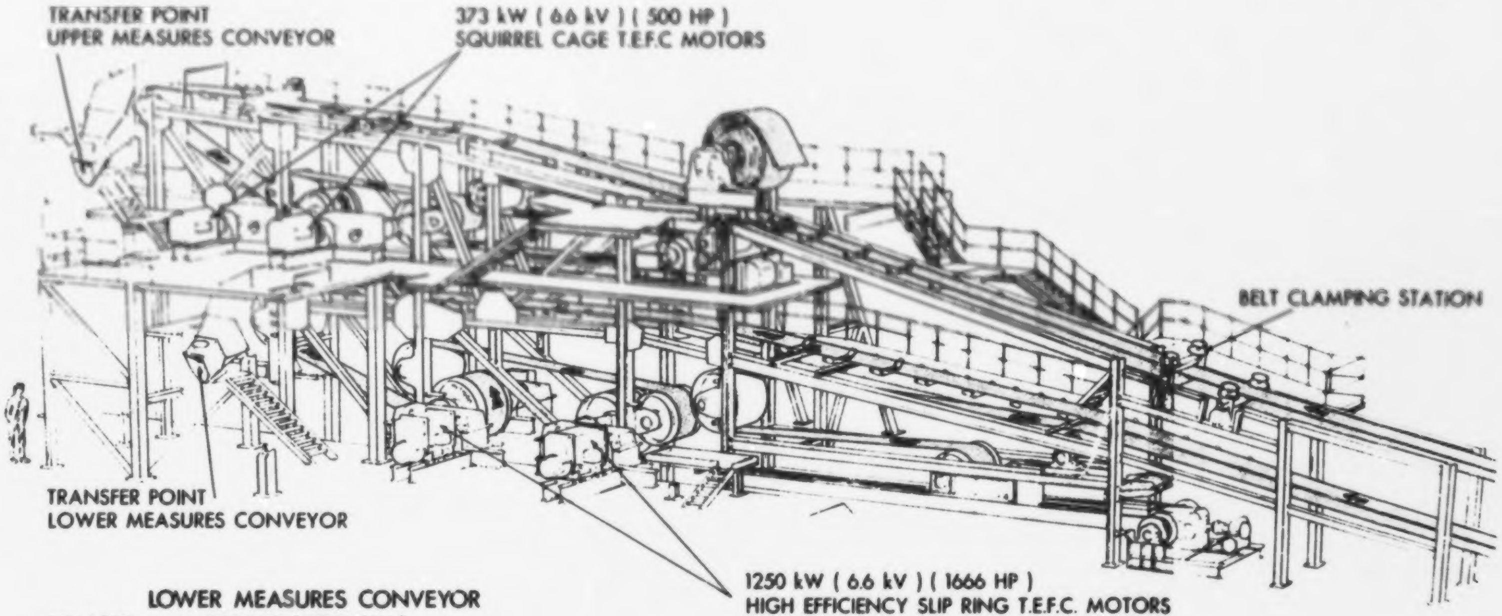
The conveyor being installed in the surface drift is unique, in that it consists of two conveyors, one running above the other. These two major surface drift conveyors, both of which commenced operation by the end of 1983, are of HUWOOD manufacture. The lower conveyor will run the full length of the surface drift which is some 2,754 m long and is powered by three 1,250 kW motors, giving a total of 3,750 kW.

This conveyor is designed to run at 3.65 m/sec and carry 1,325 tonnes per hour on 1220 mm wide steel cord belting.

The steel cord belt has a tensile strength of 7158 kg per cm width and at the time of installation is the strongest belting ever made per unit width. The conveyor belt has a total weight of 520 tonnes which is made up of 16 rolls each 350 m long and weighing over 32 tonnes per roll.

Running over the top of this conveyor is another conveyor, designed to bring coal from the Newhill Seam which is necessary because of it's quality to keep separated from the lower measured coal.

N.C.B. GRIMETHORPE COLLIERY SOUTHSIDE DRIFT CONVEYORS


TRANSFER POINT
UPPER MEASURES CONVEYOR
373 kW (6.6 kV) (500 HP)
SQUIRREL CAGE T.E.F.C MOTORS
BELT CLAMPING STATION
TRANSFER POINT
LOWER MEASURES CONVEYOR
1250 kW (6.6 kV) (1666 HP)
HIGH EFFICIENCY SLIP RING T.E.F.C. MOTORS

LOWER MEASURES CONVEYOR

HP / kW — 5000 HP (3750 kW)
LENGTH — 3012 YDS (2754 METRES)
LIFT — 761 YDS (696 METRES)
CAPACITY — 130C TONNES / HR
BELT SPEED — 718 FT / MIN (3.647 M / S)
BELT WIDTH — 48" (1200 mm)
BELT TYPE — FR 7000 STEEL CORD
(TENSILE STRENGTH 40,000 lb /INCH OR 7,000 kN–M / INCH WIDTH OF BELT)

AT THE TIME OF INSTALLATION THIS WAS THE WORLDS STRONGEST BELT / INCH WIDTH

UPPER MEASURES CONVEYOR

HP / kW — 1000 HP (746 kW)
LENGTH — 1420 YDS (1300 METRES)
LIFT — 360 YDS (331 METRES)
CAPACITY — 550 TONNES / HR
BELT SPEED — 612 FT / MIN (3.1 M / S)
BELT WIDTH — 48" (1200 mm)
BELT TYPE — 12 SOLID WOVEN

FIGURE 4-11

4.5 CABLE BELT CONVEYORS

451 BASIC SYSTEM

The cable belt system utilizes both the strength and longitudinal flexibility of a cable together with the latitudinal capabilities and versatility of the conveyor belt to the best possible advantages. The belt is carried on two steel cables which extend the full length of the system. "V" grooves moulded within the belt locate the belt on the cables. This allows for great strength parameters which translate into excellent load carrying characteristics.

The diameter of the carrying cables is determined by the length and life of the system and the load which it is carrying. If the load is light and carried a short distance, the cable diameter is small and conversely if the load is heavy and the distance long the cable diameter will be larger, (maximum 57 mm). The cable belt system has the unique feature of separating the load carrying element from the tension transmitting element.

The capacity of the cable belt system has, in its latest underground installation, exceeded 3250 tph when loaded from a series of bunkers located within 5000 m of the discharge point. This installation is located in Selby, England. This is a complex of five mines which will feed their output through staple shaft bunkers onto two conveyor systems located in drifts 200 m below the mine workings. One of these conveyor systems is a cable belt. The system has to fulfill the following:

- Single Flight Length - 14,923 m
- Vertical Lift - 990 m
- Design Capacity - 2,750 tph
- Belt Speed - 7.6 m/sec
- Drive Power - 8,750 kW

This installation represents state-of-the-art design. A paper describing this installation is to be found in Appendix B.

The cable belt system can normally handle the volume of coal required and can negotiate a gradient of up to 29° as witnessed by the installation at the Kinneil Colliery in Scotland (Fig. 4-12).

FIGURE 4-12 CABLE BELT ON 29° INCLINE

452 OPERATING LIMITS

Cable Belt conveyors have been applied to date, within the following operating limits:

1.	Drive Unit Power	26 kW - 8750 kW
2.	Number of drives per head	2
3.	Number of drives in the system	1
4.	Belt speed	1.0 to 7.5 m/sec
5.	Belt length	30 m to 30 400 m
6.	Vertical lift	-544 m to 990 m
7.	Gradient	-5° (9%) to + 29° (55%)
8.	Capacity	129 tph to 2926 tph
9.	Belt width	650 mm to 1600 mm
10.	Cable diameter	22 mm to 57 mm

These do not, of course, necessarily represent the maximum limits for cable belt conveyors, but are representative of the range of conditions in which they have been applied. Applications have been to underground conveyors (40%), surface drift conveyors (36%) and surface conveyors (24%).

453 MONITORING AND CONTROL

The monitoring and control of a sophisticated conveyor system will necessitate the use of proven computer control systems. The conveyor control portion of the system will incorporate such items as automatic or manual control of conveyors and feeder belts and discharge from bunkers, including monitoring bunker levels; automatic alarms on the system having the responsibility for initiating and carrying out corrective action; control procedures for belt start, load control and power optimization when running. The facility should also be able to monitor and control any deviations from normal operating conditons. Areas which are unique to cable belt systems will also need monitoring such as cable stretch and condition, main rope return bogey travel (to maintain design specification position on the bogey track), and rope tension weight positions.

The usual monitoring and control system comprises a control center on the surface which contains the main computer system or master station. This master station controls a number of out-stations installed in close proximity to production complex. The system must be flexible enough to allow expansion yet be simple enough to be user-friendly.

The outstations feed information from strategically placed transducers throughout the conveyor system. These transducers relay information such as bearing temperatures in such areas as the jib discharge drums, koepe wheels, deflector pulleys, gearbox bearings, sprag clutches and other areas as deemed necessary.

In addition to giving an operator demanded analog readout of conditions throughout the conveyor system, these monitoring devices are also fed into an alarm circuit which will give an immediate response (i.e. shutdown) to other than normal operating conditions of the cable belt. These alarm units usually also indicate the problem areas.

454 SAFETY

Conveyor systems are relatively safe transportation systems with the majority of accidents occurring from overheated bearings or unauthorized manriding. Bearing temperature sensors which are connected to the main control center via outstations are the frontline defence against fire hazards. Most of the fire related accidents caused by conveyor systems can be traced to bearing overheating, either the grease used for bearing lubrication ignites or the coal dust impregnated within the grease ignites.

Unauthorized manriding is difficult to control but research is under way on a device which, when mounted on a lamp battery, can be detected by conveyor mounted sensors, initiate an alarm and cause a conveyor shutdown.

Automatic fire control systems are available on the market and safety devices being constantly researched. These systems are designed for individual installations and should be investigated in detail at the design stage.

Other safety devices and controls such as broken belt indicators, blocked chute probes, belt misalignment devices, drive unit oil temperature and level, etc. are common to all conveyor systems and are discussed in more detail in other sections of this report.

455 COSTS

During correspondence with Cablebelt Ltd. they expressed concern with the basic parameters. They stated that they had generated some figures for the handling of the 2400 tph capacity over the 10,000 m distance having a 850 m lift. However, they advised that although they had designed and installed cablebelt conveying systems in greater single-flight lengths than 10,000 metres and with greater lift than 900 m, the parameters of 2,400 tph coupled with speed considerations imposed a restriction on providing a single-drive, single-flight application in this instance.

Cablebelt suggested the following alternatives:

Option 1 - 2 in line conveyors, each having a capacity of 2400 tph, each 5 km in length and having the same characteristics based on a constant slope and providing a lift of 900 m.

Option 2 - Two single-flight, single-drive conveyor systems, side-by-side, each 10 km in length with both drives at the surface each conveying 1200 tph.

Option 3 - As an alternate to Option 1 the drive cables for the furthest conveyor would be run above the first conveyor allowing surface drive for both.

The capital costs range from (CDN) $16.0 million to (CDN) $21.63 million depending on which system is selected.

The operating costs also depend on the particular system, the conditions, and labour rates. In this case the rates were selected by the manufacturer. The summary of operating and maintenance costs varied from 9 cents per tonne to 19 cents per tonne depending on the option selected.

456 SYSTEM RELIABILITY

When discussing reliability of a particular system operating examples often present the most accurate picture of how that system performs under actual conditions.

The Longannet Complex - Scotland (Fig. 4-13)

This cable belt installation was designed utilizing the following parameters as set down by the National Coal Board.

Length - 8,854 m
Lift - 326 m

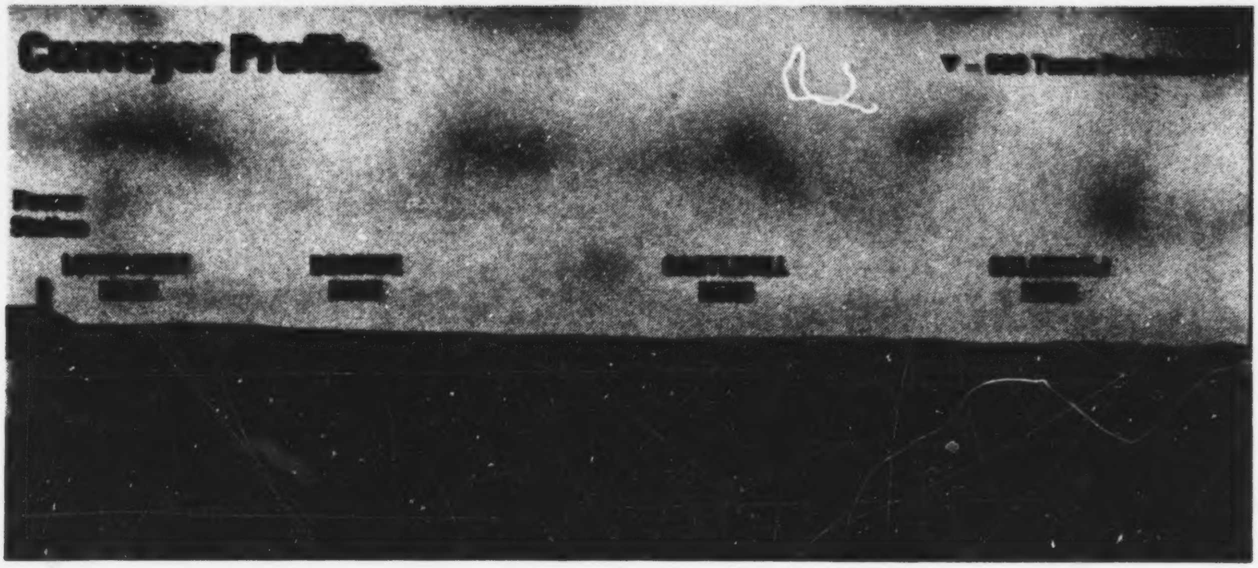


FIGURE 4-13 CABLE BELT PROFILE LONGANNET MINE

FIGURE 4-14 CABLE BELT CONVEYOR DRIVE-SELBY

Capacity - 730 tph
Belt Speed - 2-3.8 m/sec

During the first ten years of operation the cables have averaged over three years life. The replaceable poly tires on the line pulleys have an average life in excess of three years and the original belt was still in operation. The National Coal Board records show that, on average, 18 hours per year (out of 4680 working hours) are lost due to conveyor belt problems. This represents a reliability factor of 99.6%.

The operators of a cable belt sytem in western Kentucky have reported a similar reliability factor over a ten year period.

457 ADVANTAGES AND DISADVANTAGES OF THE CABLE BELT SYSTEM

Any transportation system should address the following criteria:

- There should be no reasonable restriction on the size of material carried.
- The system should have high reliability allowing three shift operation.
- The system must be designed to accommodate expansion in capacity.
- Operational problems must be kept to a minimum resulting in high availability factors.
- The annual operating cost must be kept low.
- The system should have low power requirements.
- The operation should be simple with a minimum of moving parts resulting in high availability.
- The system should have the facility of being operated with minimum personnel and preferably by remote control and monitoring.

Keeping the above in mind, the cable belt system has the following advantages:

- The drive is completely surface mounted offering central maintenance and does away with the need for flame proof or explosion proof equipment located underground.

- There is no longitudinal stress on the belt itself, this is carried by the cables.

- Ability to handle steeper gradients as material on belt has smoother ride.

- The system is not affected by differing loads.

- Straight tracking of belt as it is positively guided by ropes which, in turn, are positively guided by the support pulleys.

- Troughing idlers are not required as the belt has transverse spring steel straps moulded within the belt which allows troughability according to load.

- The reliability of the system has been documented in particular cases to be above 99%.

- The system is easily monitored and controlled.

- Maintenance is low due to relatively few moving parts when compared to belt conveyors.

- Easily adaptable to a variable speed system.

- Can operate through horizontal changes of direction by using angle stations.

- Good belt life (8 years plus).

The cable belt system does have shortcomings and these are:

- A special belt is required.

- Cable life relatively short (2-3 years).

- Cable replacement is difficult as it needs good splicing.

- Rigid linestands are required with concrete foundations.

- The system has a high dead weight to be moved resulting in high cable tension.

- A large area is required for cable routing at corner stations.

- Spares are available from only one supplier.

458 TYPICAL CABLE BELT INSTALLATIONS

.1 THE SELBY MINE PROJECT - U.K. (FIG. 4-14)

The Selby Project comprises a ten million tonnes per year production from a series of five different mines. The primary coal transportation system is centralized for the complex and consists of two parallel 15 km surface drifts which pass 70 m below the mine workings. Each drift contains a conveyor system which is fed by 11 staple bunkers. The south drift contains a steel cord belt conveyor and the north drift has a cable belt conveyor system.

The National Coal Board required the following parameters to be met:

- A single flight system would be preferred, if possible.

- The use of new or unproven technology was to be avoided as far as possible.

- The conveyor had to be able to handle the worst loading condition which was to transport 1830 tph from the furthermost loading point located at 14,920 m from the surface discharge point.

- The belt had to be suitable to a variety of other loading conditions due to the possible loading rate combinations from the 11 loading bunkers up to a maximum of 2800 tph.

After consultation with the National Coal Board a cable belt system was designed which had the following characteristics.

Length	14,923 m
Lift	990 m
Capacity	1,830 tph (from tail end)
Belt Speed	7.62 m/sec
Belt Width	1,050 mm
Drive Cable Diameter	57 mm
Drive Cable Breaking Load	240 T
Safety Factor	3.1
Drive Wheel Diameter	6.7 m

Loaded HP at Full Speed (1830 tph)	8,173 kW
Installed HP	8,750 kW
Empty HP at Full Speed	2,080 kW
Type of Surface Arrangement	Head Discharge

The only part of the installation which required a completely new design was the drive unit. The National Coal Board required 60 rpm DC electric motors made to their standard mine winder design. It is evident that although the equipment is larger it follows the basic design of previous cable belt installations.

The Selby Complex in the United Kingdom offers a comparison point between two systems which have been installed under the same conditions and are required to perform the same task. Each system is the same length, lift and capacity, each is required to handle the entire output of 10 Mtpy of five satellite mines but in effect each conveyor will transport 5 Mtpy. The conveyors are a cable belt installed in the north drift and a steel core belt in the south drift. The following comparison is made:

Location	Length	Lift	Capacity	Power	Belt Width	Supplier
N. Drift	15 km	990 m	1830 tph	8,750 kW	1050 mm	Cablebelt
S. Drift	15 km	990 m	1830 tph	10,100 kW	1300 mm	Anderson-Strathclyde

An interesting point is that although the two systems are required to do the same job the power consumption is 15% higher with the steel cord belt than the cable belt. The design specifications for the steel cord belt indicates the peak capacity to be 3250 tph versus cable belt's 2750 tph. Comment was made in "The Engineer" 14 April 1983, that:

> "In specification it (the steel cord belt) is slightly superior to the cable belt. It costs 50% more but no one is confident enough to predict which is likely to give the better value for money."

Unfortunately the systems have not been installed long enough to indicate the superiority of any one system. It should be reiterated the cable belt system is one system that will, with modifications, meet all the basic parameters.

.2 THE LONGANNET COMPLEX - SCOTLAND

During the 1960s the National Coal Board commissioned Cablebelt to install a conveyor system at the Longannet Complex (4 mines) in Scotland (Fig. 4-13).

The installation was designed to have a length of 8854 m with a lift of 326 m, the capacity was designed at 730 tph and the installed power was 1500 kW for the surface drive unit. The feed to this belt is computer controlled from different feed stations, so limited blending can take place.

The uniqueness of this installation is that it has been operating since 1968 so performance records have been maintained which allows a statistical review. Some of the documented figures are as follows:

- The original belt is still in service.
- The reliability factor is 99.6%.
- The main gearbox has maintained 100% reliability factor throughout 50,000 running hours.
- The operating costs show that during the first ten years of operating the average cost was 1.5 cents per tonne kilometre.

459 WORLD USAGE

Since the early 1950s cable belt systems have been installed on six continents comprising close to two hundred separate conveyor installations. These systems have been installed both underground and on the surface, have varied in length from 30 metres at a steel mill in Belgium to 30 kilometres at a bauxite mine in Australia, have moved such diverse materials as coal, chalk, stone, schist, diamondiferous gravel and potash and have vertical lifts from minus 544 m to plus 990 m.

There are now more than 183 cable belt systems in operation around the world including 40 in the U.K. coal mines. Operating countries include U.K., U.S.A., Canada, France, India, W. Germany, Japan, Africa, S. America, W. Indies, Australia and E. Europe.

4.6 HYDRAULIC SLURRY TRANSPORTATION SYSTEMS

461 SYSTEMS AND CAPACITIES

Hydraulic coal-water slurry transportation systems that are used to transport large volumes of fine coal over considerable distances have been in use on the surface for many years and it can be said that its technology is well proven. Such systems can now be reliably designed to transport tonnages in the range of 15 to 20 million tonnes per year over distances of at least 1,000 km. Systems that can handle larger sizes of coal (25 to 100 cm), over long distances have not been so well developed and such installations can be considered more experimental.

The development of both fine and coarse coal-water slurry transportation systems for use in underground coal mines has not proceeded as quickly as the surface systems and compared with rail and conveyor belts can be considered to be no more than a minor contributor to the overall transportation picture.

At the present time major underground coal-water slurry transportation systems are known to be in use in Canada, the USA, Japan, China, the USSR and Poland.

In Canada gravity assisted, open flume systems have been in use since 1970 and, by developing the underground mine roadways on suitable gradients, 6 to 7 degrees for steel flumes and 3 to 4 degrees for low friction plastic flumes, low water volumes have safely and reliably transported almost one million tonnes per year of raw coal from a series of underground coal mines. At the same mining property in Canada non-gravity assisted systems utilizing electrically powered slurry pumps have been safely and successfully operating since 1978 pumping coal-water slurry at up to 800 tph along an 800 m long 12 degree tunnel to a coal-water slurry dewatering plant located approximately 1000 m from the mine mouth through slurry pipe lines. In the gravity assisted system coal sizes have been limited to a maximum of 150 mm and in the pumping system to approximately 10 mm (although the pumping system is designed to handle a maximum size of between 50 and 75 mm).

In an underground coal mine in the USA a larger maximum coal size system has been developed and is in use. This system contains two separate pumped subsystems. A mobile system is used to hydraulically transport sized raw coal directly from a continuous miner to the main slurry pumping system and has a capacity in the range of 500 to 600 tonnes per hour. The larger or primary system receives coal from one or more of the smaller mobile systems and powered by a series of centrifugal slurry pumps sends it to the surface through a 250 mm dia. slurry pipe line. The production capacity of this primary coal-water slurry system is approximately 800 tph and it has a built in surge capacity of 300 tonnes in the coal/water sump.

In the USSR coal-water slurry systems regularly transport over 10 million tonnes of coal as coal-water slurry out of eleven underground coal mines. Additionally, in the Ukraine a somewhat different coal water transportation system, an air lift, transports well over 1 million tonnes of coal per year out of a deep coal mine.

In Japan, and up till recently West Germany, a different primary coal-water slurry transportation system, the hydro hoist is used to transport coal out of deep underground coal mines. The hydro hoist although not widely used has been used to transport up to approximately 450 tph of coal over lifts in the range of 850 m for many years and can perhaps be classed as the more proven of the systems when very high lifts are required.

In China variations of both the hydro hoist and the centrifugal slurry pump arrangements are reportedly in use and transporting in the region of 10 million tonnes per year of coal from underground mines. Unfortunately no other data is readily available at this time to substantiate or expand the present state of Chinese technology.

The actual range of installed and fully proven coal-water slurry transportation systems can therefore be determined to be:

a) Gravity assisted, open flume systems, at least 1,000 to 1,500 tph and possibly considerably higher. Coal sizes from 0 to at least 250 to 300 mm. Minimum gradients using normal steel flumes and high volumes of water are approximately 6 degrees and when special low friction flume lines are used some were in the region of 4 degrees. If maximum coal sizes are reduced to around 5 mm these gradients can be reduced even further.

b) Secondary or face area portable or semi portable slurry transportation systems can pump coal with sizes up to 100 mm and tonnages in the 500 to 600 tph range for the portable units and up to 800 tph in the semi portable units. The systems capacity may be increased considerably as the technology is still developing;

c) Primary or stationary systems designed to transport all of the coal out of a mine can be further broken into three separate systems with the following capacities:

    i) Centrifugal pumps, individual heads to approximately 300 m, production to 1,000 tph. With pumps in series and parallel pipelines, heads and capacities can be extended to meet needs.
    ii) Hydro hoists, heads to approximately 850 m, production to 450 tph.
    iii) Air lifts, heads to 250 m, production to 600 tph.

462 ABILITY TO MEET THE STUDY REQUIREMENTS

.1 Secondary System

This lower capacity, 600 tph, can be accommodated by both the gravity and the mobile or semi mobile transportation systems.

.11 Natural gravity systems A simple gravity assisted open flume line system can transport the required 600 tph production level and operate consistently and reliably with few stoppages, breakdowns or maintenance. As it has no moving parts or power supply outside its pumps, which are located in a designated "safe area", monitoring and control is extremely simple and can be achieved at very low cost. For similar reasons and because the coal is always immersed in water the system is extremely safe and generates negligible dust of any kind. Operating costs and capital costs are extremely low. It should be understood, however, that as the product is a coal and water slurry mix additional costs are often incured to separate them. In all systems the reliability of the whole is often tied to the simplicity of its individual parts, as this system has the least number and simplest parts it is perhaps the most reliable of all systems.

Advantages

- able to handle the full 600 tph production requirement
- reliable and safe
- generates minimum amounts of airborne dust
- suppresses the release of methane from the coal during coal transportation
- length easily adjusted.
- capacity can be easily varied.
- personnel operating, maintenance, installation and removal skill requirements are low

Disadvantages

- requires suitable gradients to operate.
- product is immersed and mixed with water hence some treatment, such as dewatering, is required before it can be transported up gradients or shafts using conveyor belts, rail haulage or shaft cage or skip systems.

Although no precise figures are available we estimate that over 30 million tonnes of coal are transported internationally in underground mines and around 2 to 3 billion tonnes on the surface in coal preparation plants using gravity assisted systems.

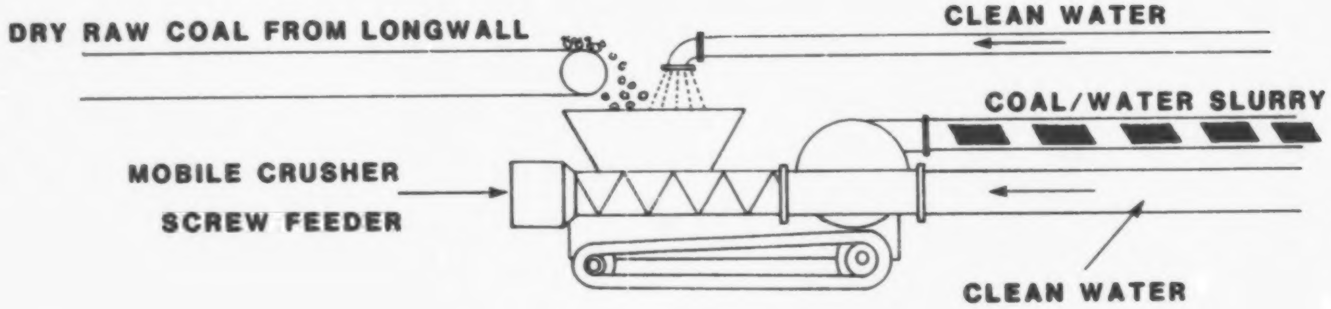


FIGURE 4-15 SECONDARY TRANSPORTATION SYSTEM MOBILE LONGWALL COAL/WATER SLURRY PUMP UNIT

.12 Pumped Systems A simple coal sizing and pumping device is available in mobile and semi mobile formats that can transport the required 600 tph of raw coal.

The mobile unit has been in operation in its original and present form for approximately ten years.

Figure 4-15 shows the basic system parts which are essentially, the coal sizing and pumping unit, a flexible hose to allow the system mobility, a rigid steel slurry pipeline outbye of the hose and a clean water pipeline bringing water to the pumping unit. The semi-mobile unit is skid mounted.

Like the open flume gravity system the general lack of or least reduction in the number of prime movers and moving parts in the system ensure that both capital and operating costs for this system are very low. Naturally this helps keep reliability high and personnel skill requirements low.

Advantages

- able to handle the full 600 t/h production requirement
- reliable and safe
- generates minimum amounts of airborne dust
- suppresses the release of methane from the coal being transported
- length easy to change
- personnel requirements for maintenance, operation, installation and removal low and personnel skill level requirements are generally low
- exposure of personnel to moving equipment type accidents is low
- can be used to transport the coal out of the mine as a slurry where distances and changes in elevation are not too great.

Disadvantages

- some reduction in coal size takes place
- the product is wet and mixed with high volumes of water hence some treatment, such as dewatering, is required before it can be transported out of the mine up significant elevation changes by conveyor belts, rail or shaft systems.
- this system is only in use in one mine in the USA at this time and although it can be considered proven it is not fully developed by the coal industry.

.2 Primary System

This much higher capacity system with its strict gradient requirements, high change in elevation from one end to the other and substantial surge requirements can be accomodated by some of the main hydraulic coal-water slurry systems.

.22 Gravity A simple gravity assisted coal-water slurry transportation system can transport the required 2400 tph if the gradients are adequate and in the correct direction. Unfortunately the adverse gradients that are stated mean that this natural gravity system can only be used to transport coal into the mine and not out of it. Its main use therefore is to transport coal to the lowest point of the mine for onward transport by other methods.

.23 Pumped Systems Several hydraulic coal-water slurry systems that do not depend upon assistance from natural gravity are in use throughout the world and could be considered for this application.

.231 Airlift The rather old fashioned air lift that was used quite commonly to dewater coal mines many years ago was developed as a coal transportation system in the Ukraine after the second world war. At the end of the war the underground coal mines were all flooded by the retreating occupying army and to dewater them the local mining people installed and used air lifts. After the mines had been dewatered it was realised that these same air lifts, with modifications, could be used to transport coal out of the mine as a slurry; hence, when hydraulic mining was introduced to the mines it was a natural extension to install an updated coal-water slurry air lift. A modern air lift that has been in operation for many years at the Red Army Mine in the Ukraine and regularly transports approximately 1.5 million tonnes of raw coal per year some 460 m vertically from the underground working levels to the surface with coal size ranges in the region of 0 to 150 mm and the water to coal ratio is approximately 7 to 1. Several papers on the subject state that the system is able to transport coal at approximately 400 to 600 tph with fairly high levels of reliability. Personnel requirements for maintenance and operation are low, capital requirements for the shaft installation are low, however the capital and operating costs for the high capacity compressor installation on the surface are high.

Figure 4-16 presents a generalized working arrangement for the system.

Air lifts, by design are intended for use in vertical or almost vertical mine shafts, particularly when transporting a coal-water slurry, because of this they cannot operate satisfactorily on the gradients specified in this study.

.232 Hydro-Hoist (sometimes called the "pipe feeder hydraulic coal-water slurry system"). Hydro-hoists have been in use as a tansportation medium for many years and are being used to transport coal and other materials both in mines and elsewhere. The better known hydro-hoists used in the coal mining industry are those developed in West Germany to be part of their hydraulic mining systems and a similarly system located in the Sanagowa hydraulic coal mine in Hokkaido in northern Japan. These systems normally transport coal that has been pre-sized to a maximum of 100 mm at up to approximately 750 tph of coal and water or 450 tph coal over several thousand metres horizontally and up to approximately 850 m vertically.

The hydro-hoists in use in the Sanagowa mine in Japan and the Hansa mine in Germany are the better known underground coal mine systems and contain the following basic characteristics. The coal and water are delivered to a collecting sump which acts as a damper for any surges in feed rate and is the feed point for the hydro-hoist itself. Collection or retrieval of the coal from the sump is achieved using various methods from scraper chains to dredge pumps to eductors, etc. The dredge pump, which is the most popular, collects the coal as a thickened slurry (some of the water has been drained off) and injects it into one of the chambers of the hydro-hoist from which it is in turn ejected into the main slurry delivery line using clean water under sufficient pressure to push the slurry out of the mine.

The rationale behind the main parts of this system (Fig. 4-17) is (a) collect the coal and water into a large sump to reduce surge and help control the systems feed, (b) allow some water to drain off the slurry to thicken it before pumping it into the pipe feeder so increasing overall system efficiency (c) use a low head type centrifugal pump to load the slurry into the pipe feeder (d) use high pressure positive displacement pumps to deliver the high pressure water needed to push the thick coal-water slurry up the main mine slurry pipeline. (The separating of the coal slurry from the costly high pressure pump prevents extensive wear problems caused by pumping raw coal while still benefiting from the pump's high efficiency level). As this cycle would only provide a crude cylical coal flow more than one, often 3 or 4 pipes are used as a set in a pipe feeder which act somewhat like a "six shooter" type revolver with one "shot" of coal-water slurry being injected into the slurry delivery pipe after another in a continuous chain.

The hydro-hoist as a single unit would not be able to transport the 2,400 tph of coal the 10,000 m horizontally and 900 m vertically required in this study. As with all hydraulic systems however it would be quite simple to install suitably sized units in parallel and in that way meet the tonnage requirements. Similar to

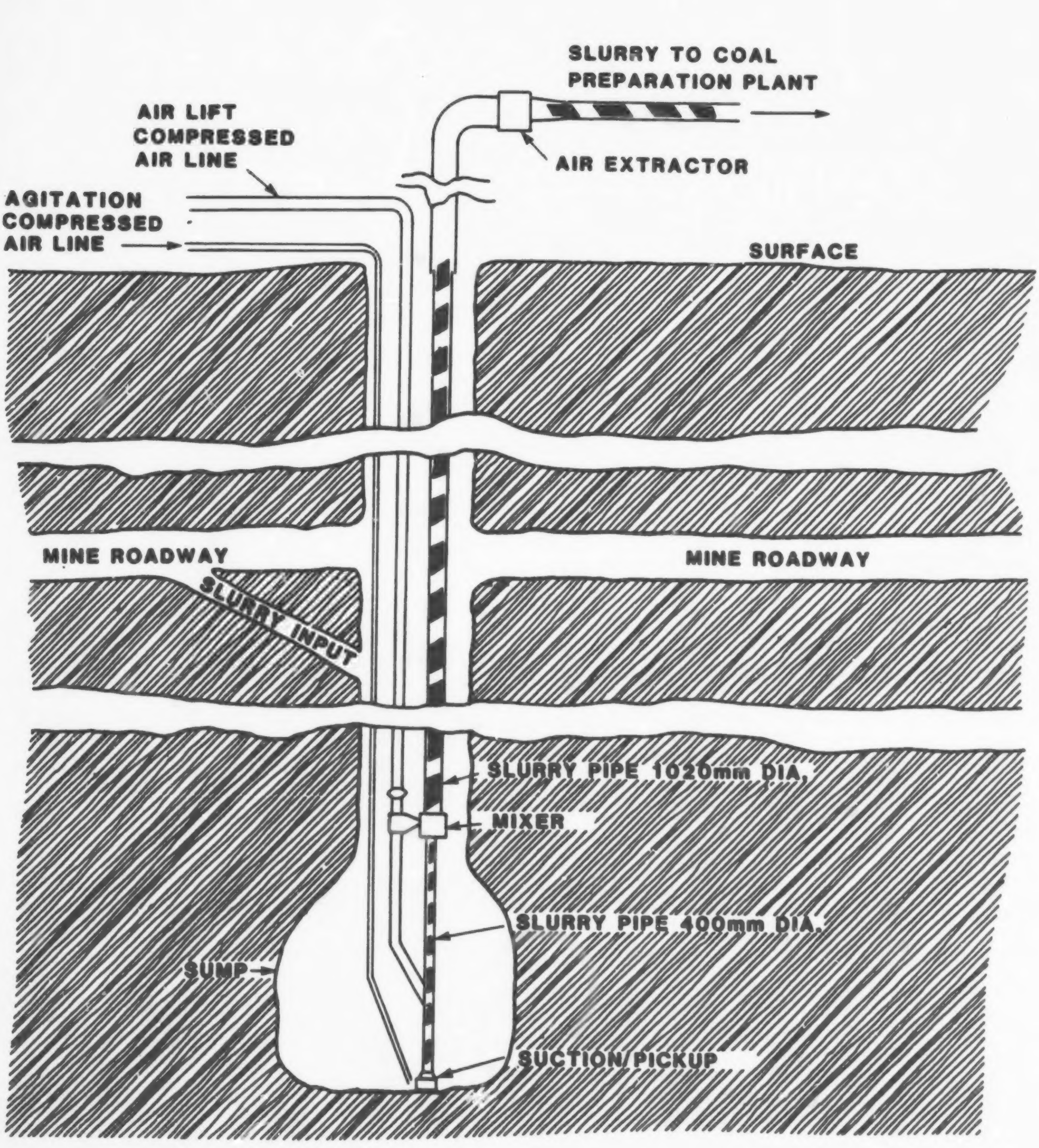
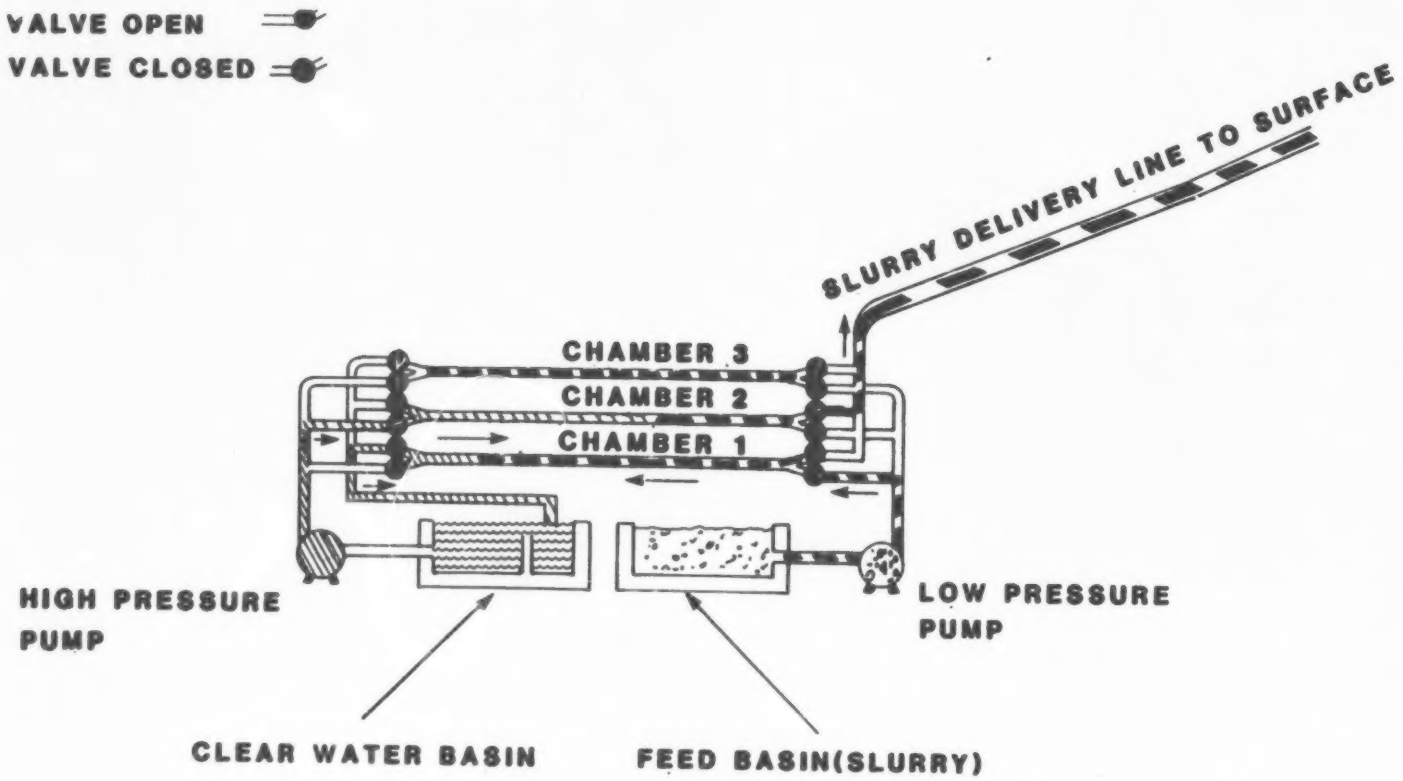


FIGURE 4-16 PRIMARY TRANSPORTATION SYSTEM AIRLIFT-COAL/WATER SLURRY LIFTING SYSTEM



CHAMBER 1 IS BEING CHARGED
CHAMBER 2 IS PUMPING INTO THE SHAFT LINE
CHAMBER 3 STANDING CHARGED IN WAITING POSITION

FIGURE 4-17 PRIMARY TRANSPORTATION SYSTEM COAL/WATER HYDRO HOIST SYSTEM

the other underground hydraulic coal-water slurry systems the hydro-hoist is quite reliable.

One requirement of the study is to be able to handle surges in coal production that could be as high as 7,200 tph for periods up to 5 minutes. Unlike most dry transportation systems, all of the coal entering the hydraulic coal-water coal transportation system will automatically flow into a large surge sump prior to being introduced to the actual transportation system itself. Because of this, almost any reasonable surge can be easily catered for as long as adequate capacity is built into the sump.

Advantages

- able to handle the full 2,400 tph production requirement
- able to handle the full 2,400 tph x 3 surge for the required 5 minutes
- simple to operate and automate
- safe and reliable
- generates negligible airborne dust
- suppresses methane emission from the coal during transportation
- personnel skill requirements are low except in the slurry hydro-hoist room
- personnel requirements low
- maintenance costs are low

Disadvantages

- the product is wet and mixed with a large volume of water hence dewatering is required before it can be used
- this system is used in only a few places in underground coal mines
- the coal product is subjected to some size degredation
- in mines with high volumes of very hard rock in the product, wear on the valves in the pipe feeder occur.

.24 Centrifugal Pump Based Coal-Water Slurry Systems Coal-water slurry transportation systems are in use in underground coal mines in many countries particularly in Canada, the USA, the USSR, and China. They have proven to be the most popular primary slurry transportation system, accounting for up to 90 percent of all hydraulically transported coal. These systems that are in use have capacities from between 800 and 900 tph in Canada and the USA to somewhat more than 1,000 tph in the USSR. At the Jubileynaya Mine in the USSR annual production from such a system is reported to be 3.6 million tonnes per year or over 15,000 tpd. The elevation changes that these systems can accommodate is controlled largely by the ability of the centrifugal pumps to

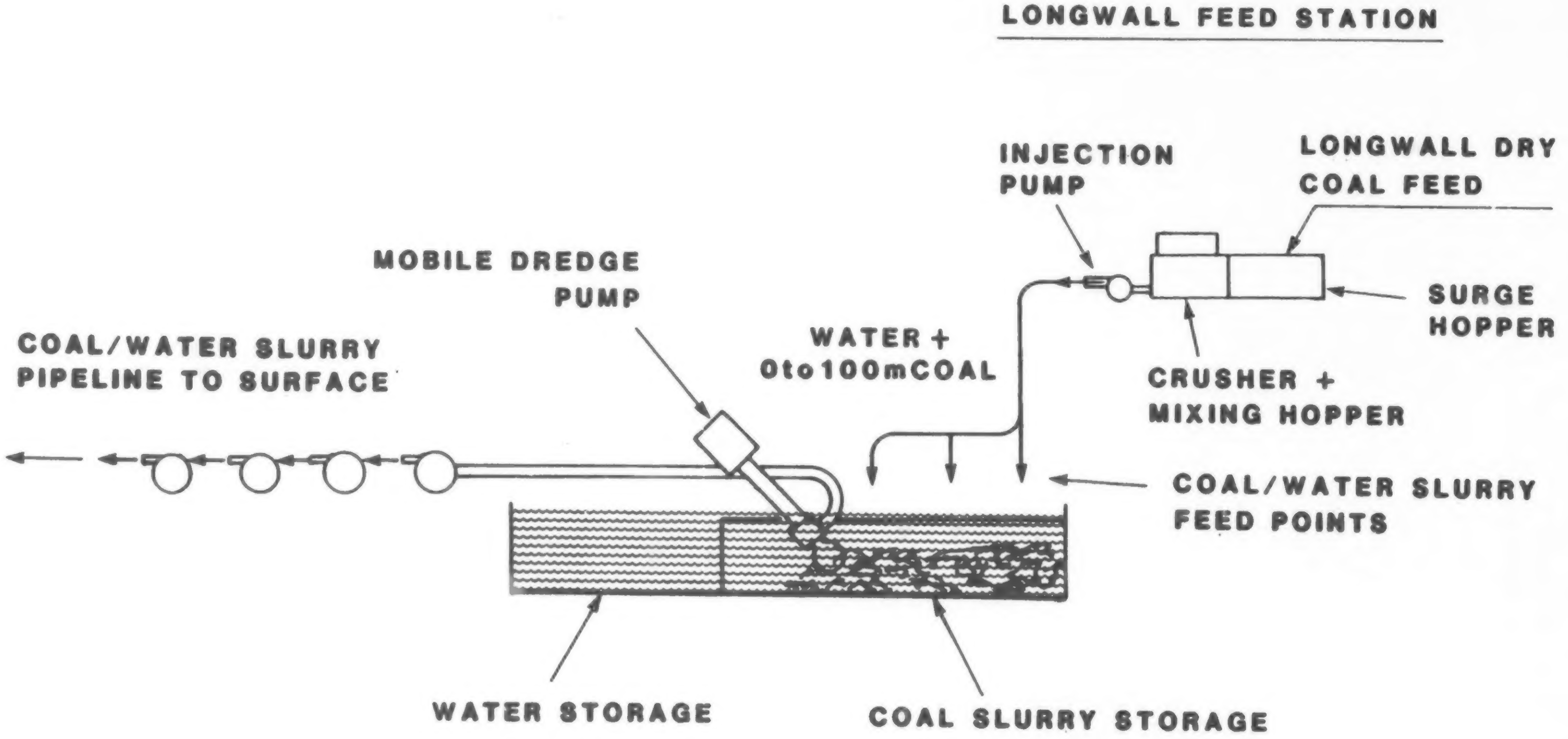


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FIGURE 4-18 PRIMARY TRANSPORTATION SYSTEM COAL/WATER SLURRY PUMPING SYSTEM

generate the required pressures. Largely because of this most systems lift the coal-water slurry in the region of 300 to 400 m and transport it horizontal distances of no more than a few thousand metres. In both the USA and the USSR the system is extended by using booster pumps in series (Fig. 4-18).

Like all of the hydraulic systems this one would not be able to transport the full 2,400 tph the required distance and change in elevation in a single system. As with the other slurry systems, it would most likely have to be developed to allow two or more systems to be in parallel. By paralleling systems not only could the total production requirement be achieved but the system would be able to operate consistently with few unscheduled stoppages.

The inbuilt sump, which is a normal system requirement, will be able to handle the forecast surge without problems provided the sump is built of the correct size.

Perhaps the most serious problem with the hydraulic slurry pumping system is the need to maintain the sumps and slurry pumping station at the lowest point of the mine. In a mine which is continuously advancing down the dip, this means that either the main development has to be extended far beyond the working places or the sump and pump station have to be moved regularly. In the first case, expensive and time consuming development is required, and higher than normal pumping costs are incurred. In the second case, considerable additional excavation and installation costs are incurred. In practical terms, this one factor alone will tend to eliminate slurry pumping systems from consideration.

Maintenance costs are generally low with very little day to day maintenance required, but replacement or repair of slurry pumps, and pipelines may become expensive if sandstone or other abrasive materials enter the system. Other operating costs are low except for the electrical power requirements. In general hydraulic slurry pumping systems power costs will likely be around 25 percent more than comparable conveyor belt systems.

Capital costs are largely not available as the present slurry pumping system owners are reluctant to divulge costs. From our best estimates we would expect a system designed to meet the presented requirements to cost somewhere in the region of \$25 to \$35 million.

The system's overall simplicity and the duplication of many parts in the parallel systems make this a very reliable system. By carefully sizing storage sumps it is possible that the slurry system can operate continually around the clock while the coal production machines are limited to perhaps 10 to 15 hours out of every 24 hours because of various problems.

Advantages

- able to handle the full surge requirements
- safe and reliable
- simple to automate
- generates negligible airborne dust
- suppresses methane emissions from coal during transportation
- other than for the slurry pumping complex personnel, skill requirements are low
- personnel requirements are low
- maintenance costs are generally low

Disadvantages

- need to keep slurry pumping station at the lowest point of the mine
- a reduction in product size will take place during the time it is in the transportation system
- the product is wet and mixed with large volumes of water hence some treatment is required before it can be used
- capital costs are high
- power costs are high; possible 25 percent greater than a similar capacity conveyor system
- the system has not been used at the type of heads (dynamic plus static) planned so that this could be an extension beyond existing technology and mean special pumps would have to be designed or the system augmented by a series of lower head booster systems along the slurry pipelines.

The two slurry pumping systems in use in North America and Western Canada use similar technology as do such systems in the USSR. There are some basic differences however. The Canadian system, even though it can pump up to 50 to 75 mm material, only transports -10 mm material and water and after separating the +10 mm material from the -10 mm coal and water, the +10 mm material is transported out of the mine on a normal conveyor belt. Additionally the system collects and mixes the coal-water slurry it will pump directly from a sump using specially located "water lances" to ensure the slurry is adequately mixed and within reasonable density ranges. Fine tuning of the slurry concentration is achieved by adding water between this pick-up point and the first of the slurry pumps or changing the amount of agitation caused by the water lances.

A benefit of the arrangement is that most non-coal products, such as wood, rock, scrap iron or steel etc. are removed by the screens and transported on the conveyor belt and do not enter the sump and because of this the slurry system receives less wear or abuse and is more reliable. Additionally, the small particle size of the coal being pumped allows the slurry to be transported through the pipes at relatively low velocities which again reduces wear on the pumps and pipelines.

The system being used in the USA is based on the concept that all coal should pumped and conveyor belts eliminated. To do this the coal must be sized to a maximum of 100 mm, and all of it pumped out of the mine as a coal-water slurry. Similarly all of the Soviet slurry pumping systems use the same concept and after sizing the coal, this time to a maximum size of 150 m they pump all of the coal out of the mine.

We have been unable to determine precisely how many coal-water slurry pumping systems are in use internationally, however, we believe that there are between 8 and 10 systems in the USSR, 6 and 8 systems in China and two in North America for a total of between 16 and 20.

463 DEWATERING OF HYDRAULICALLY TRANSPORTED COAL-WATER SLURRIES

In all cases where the coal is transported out of the mine using hydraulic transportation methods the coal requires some "treatment" before it can be utilized. In very special cases this treatment could be limited to sizing and partial dewatering for use as a coal-water slurry feed to specially designed coal-water slurry furnaces. Normally the coal requires "cleaning" in a coal cleaning or coal preparation plant before use; hence, it must either be separated from the water before entering the coal preparation plant or the coal preparation plant designed to accommodate the coal-water slurry feed. Figure 4-19 is a generallized dewatering system design that provides the basis for a suitable dewatering plant that could be located either near the mine portal or adjacent to or become part of a coal preparation plant.

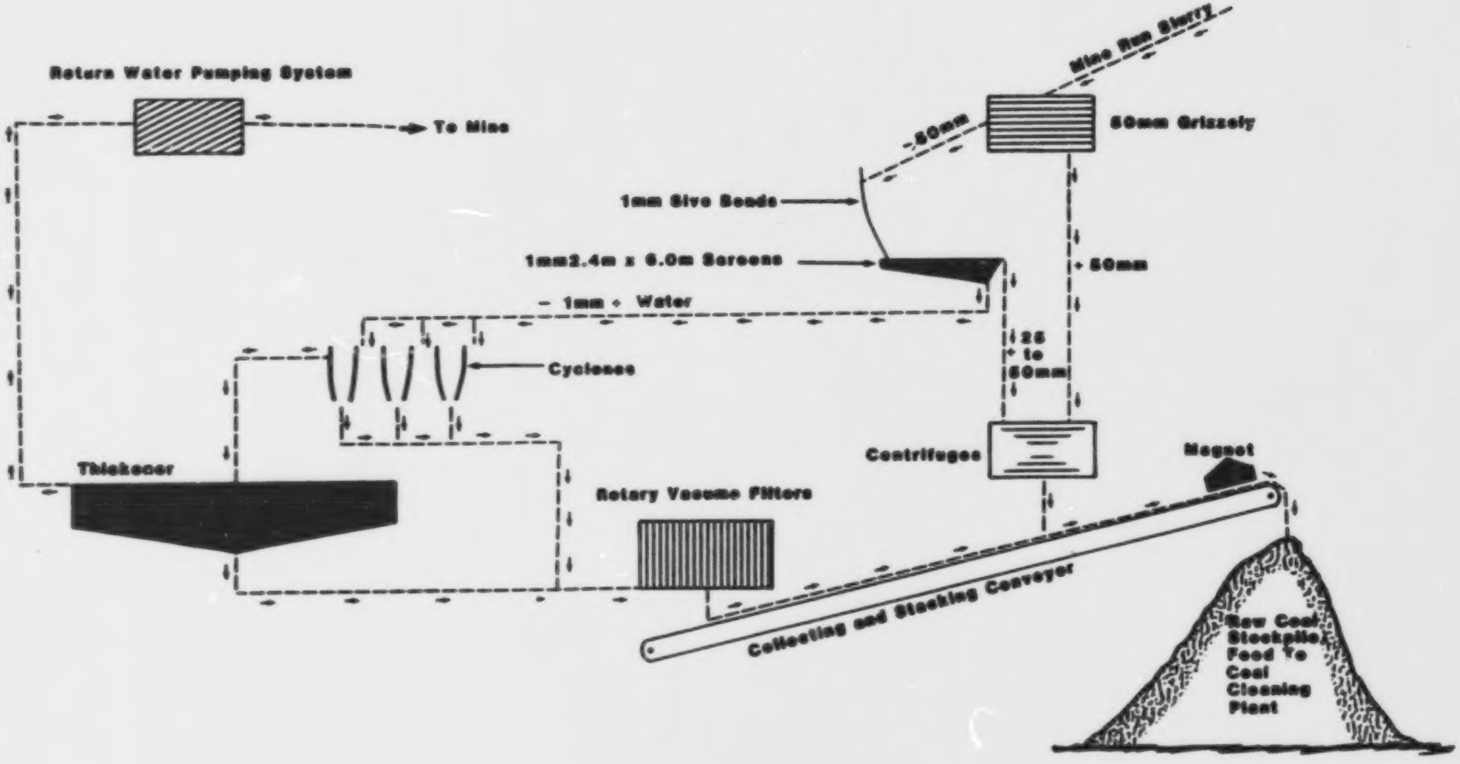

FIGURE 4-19 TYPICAL COAL/WATER SLURRY DEWATERING PLANT

PART 5

SYSTEM ANALYSIS

PART 5 - SYSTEM ANALYSIS

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5.1 INTRODUCTION

The study specifications that each potential transportation system must meet are as follows:

Primary or main system

- Production to 2400 tph
- Surges in production to 7200 tph (for 5 mins)
- Length of total system 10,000 m broken down into a 7000 m long section that originates at the mining limit and feeds onto the 3000 m section to the surface at a 45 degree change in direction of the conveyor system.
- Total lift-900 m (725 m in the 3000 m length).

Secondary system

- Production-350 to 600 tph
- Surges - nil
- Length unknown but not likely to exceed 2,000 m
- Change in gradient 25%

The examination of the various transportation systems undertaken in Parts 3 and 4 of this report has shown that only two major systems are capable of handling the tonnages, gradients and lengths indicated above. These are belt conveyors and slurry pumping systems.

Discussions were held with major conveyor manufacturers in Europe and USA (Huwood, Dowty Meco, Anderson Strathclyde, Krupp and Cable Belt) and with operators of coal slurry pumping systems in Canada and USA (Consolidation Coal Company and Westar Mining), and the analyses have been based on the preliminary data provided by them. In making such an analysis, we have taken into account the comments made by the companies.

Firstly, that the maximum tonnage requirement is high, particularly when related to the maximum tonnage rate for the conveyors for the worlds largest underground coal mine - the Selby Mine in the U.K. At this mine, the expected annual output of 10 million tonnes per year requires a conveyor capacity of 1800 tph. We are sure that none of the underground mines are expected to reach this output. However, the conveyor suppliers have attemtped to identify the consequences of an output rate of 2400 tph. Similarly, the slurry pipeline operators have attempted to cover the requirement.

TABLE 5-1

Variation of Belt Capacity with Loading Point Location - Selby Mine

Distance from Surface	Loading Point (Bunker)	Belt speed (m/sec)	Capacity (tph)
A STEEL CORD CONVEYOR			
4889 m	(B1)	2.5	725
7453 m	(B2)	3.94	1225
7654 m	(B3)	5.90	1825
7968 m		5.90	1850
8180 m		5.90	1875
8392 m		5.90	1925
8604 m		5.90	1950
8816 m		5.90	2000
9028 m		5.90	2025
9240 m		5.90	2050
9452 m		5.90	2100
9664 m		5.90	2125
9876 m		5.90	2125
9910 m	(B4)	5.90	2525
10010 m	(B5)	8.40	2525
12253 m	(B6)	8.40	2650
12383 m	(B7)	8.40	2025
14528 m	(B8)	8.40	2250
14628 m	(B9)	8.40	2075
14798 m	(B10)	8.40	1950
14909 m	(B11)	8.40	1800
B CABLE BELT			
4889 m	(B1)	7.62	4420
7654 m	(B3)	7.62	3212
10010 m	(B5)	7.62	2483
12383 m	(B7)	7.62	2136
14909 m	(B11)	7.62	1830

Secondly, comment has been made that it is difficult to specify and cost any system without knowing the specific layout, locations of various feeder points to the system and their rates, operating schedules on an hourly and annual basis, and specific gradients and changes. This second point is amply illustrated by the data given in Table 5-1. This shows how the carrying capacity of the Selby steel cord and cable belt conveyors vary according to the location of the loading point along the 15 km length.

The slurry pumping system does not suffer this problem since the pumping station is located in the current lowest point of the mine. However, it has its own unique problem, namely the need to keep the slurry pumping system at the lowest point of the mine. This is a very difficult task in a mine which is continuously advancing down dip.

These comments aside, we have, in the following sections attempted to summarize the major critical factors for (a) the major conveyor systems; (b) the slurry pumping system.

5.2 PRIMARY SYSTEMS - CONVEYORS

There are three primary belt conveyor systems which are candidates for this task.

1. Conventional belt conveyor drives using booster conveyor drives and fabric belting.
2. Conventional belt conveyor drives using steel cord belting.
3. Cable belt conveyors.

Table 5-2 lists the perceived requirements for each system to provide either

a) a single flight conveyor over the 10 km length with a 45° change of direction; or

b) a single flight conveyor in each leg - the 3000 m leg from surface to the change of direction, and the 7000 m leg from the change point to the mine dip boundary.

TABLE 5-2

Comparison of Conveyor Capabilities

	Cable Belt	Steel Cord Belt	Booster Drives
1. **Single Flight** 10,000 m, 900 m lift, 45° direction change, 2,400 tph	Cannot do as single flight even though can negotiate change of direction.	1. Cannot do as single flight with direction change (curves unacceptable). 2. Single flight with no direction change would require approximately 10,400 kW.	1. Cannot do as single flight with direction change (curves not acceptable). 2. Single flight with no direction change would require approximately 9,000 kW.
2. **Multiple Flight - First Leg** 3,000 m, 725 m lift, 2,400 tph	Maximum capacity of single flight conveyor for this leg is 1,900 tph governed by rope limits (57 mm diameter).	Single drive head at surface, using 1,800 mm belt at 3.8 m/sec requires approximately 6,700 kW power. Belt Factor of Safety = 6.2:1 with ST7000 steel cord belt.	Drive unit at surface (1,200 kW) plus four booster drives (1,200 kW) with belt at 3.8 m/sec at width of 1,400 mm. Factor of safety at 9:1 for type 15 belt.
	Alternatives 1. 9,600 tonne bunker at change of direction to absorb difference between second leg belt at 2,400 tph and first leg at 1,900 tph. First leg belt runs 6 hours longer to convey total output. Approximate power 4,600 kW at 4.3 m/sec speed for 1,300 mm belt.		Alternative Use steel cord belting at 1,400 mm, 3.8 metres/sec with drive head at 2,400 kW and two booster drives at 2,200 kW. Factor of safety 6:1 with ST4000 steel cord belt. (1) Required booster length may exceed available conveyor length.

TABLE 5-2 (Cont'd)

	Cable Belt	Steel Cord Belt	Booster Drives
2. Multiple Flight - First Leg (Cont'd)	Alternatives (Cont'd) 2. Twin cable belts, side by side at 1,200 tph, 4.3 m/sec, 950 mm belt. Approximate power 3,050 kW. This option would be approximately 20% more expensive (capital cost) than Alternative 1.		
- Second Leg 7,000 m, 175 m lift, 2,400 tph	(a) Drive unit placed underground at change of direction, 1,300 mm belt at 4.3 metres/sec requires 2,450 kW power. (b) Drive unit placed on surface and cables run above conveyor in first leg. Power requirement 2,750 kW with about 8% increase in capital cost of conveyor.	(a) Drive unit underground, 1,400 mm belt at 3.8 metres/sec required 3,900 kW with safety factor of 7:1. (b) Drive unit underground, 1,800 mm belt at 2.54 metres per second requires 3,700 kW with safety factor of 6:1.	Drive unit underground 1,400 mm belt at 3.8 metres/sec with drive unit and two booster drives totalling 3,600 kW (say each approximately 1,200 kW) using type 12 but with a 9:1 safety factor.

521 10 KM SINGLE FLIGHT

.1 Change of Direction

The first concern is the change of direction. Only the cable belt system has a well proven design in operation by which the conveyor can be made to change direction horizontally. The angle station can accommodate changes upto 180°.

Angle stations for conventional belts are in the course of development. To date, these have only been used with drive powers of 120 kW (Fig. 5-1). One manufacturer (Anderson Strathclyde) claimed that the angle station could be capable of handling the high horsepowers, but we believe that this technology is many years away from application to high horsepower conveyors. Other suppliers tend to agree with us.

Modern conveyor technology has developed the means to take conveyors round curves, albeit of large radius. Requirements seem to vary according to belt size and duty ranging from 1000 m to 2500 m radius (Fig. 5-2). Such large radii may or may not be practical being dependent on specific mine and deposit geometry.

.2 Suitable Systems

As can be seen from Table 5-2, neither the cable belt, nor the steel cord belt can supply a single flight conveyor capable of handling 2400 tph, angle stations and curved conveyors not withstanding. The power requirements for a single surface located drive head are too great for present technology (belting, cables, drives). Only the booster drive conveyor system has the capability to offer a single flight conveyor, but only if a long radius curve is accepted.

Cable belt are able to offer one option which removes the need for a second drive unit at the change point. This involves locating the drive unit for the second leg (7 000 m) on the surface and running the cables for the second conveyor above the first leg conveyor. Whilst this is not then a single flight conveyor, it does remove the second drive unit from underground. However, the cable belt conveyor is limited to 1900 tph capacity as a single conveyor for the first leg.

.3 Conclusions

Belt conveyor technology is not yet at the stage where it is practical and feasible to enable a single flight conveyor to be supplied to meet the system capacities as given in the statement of work for the State of Art review.

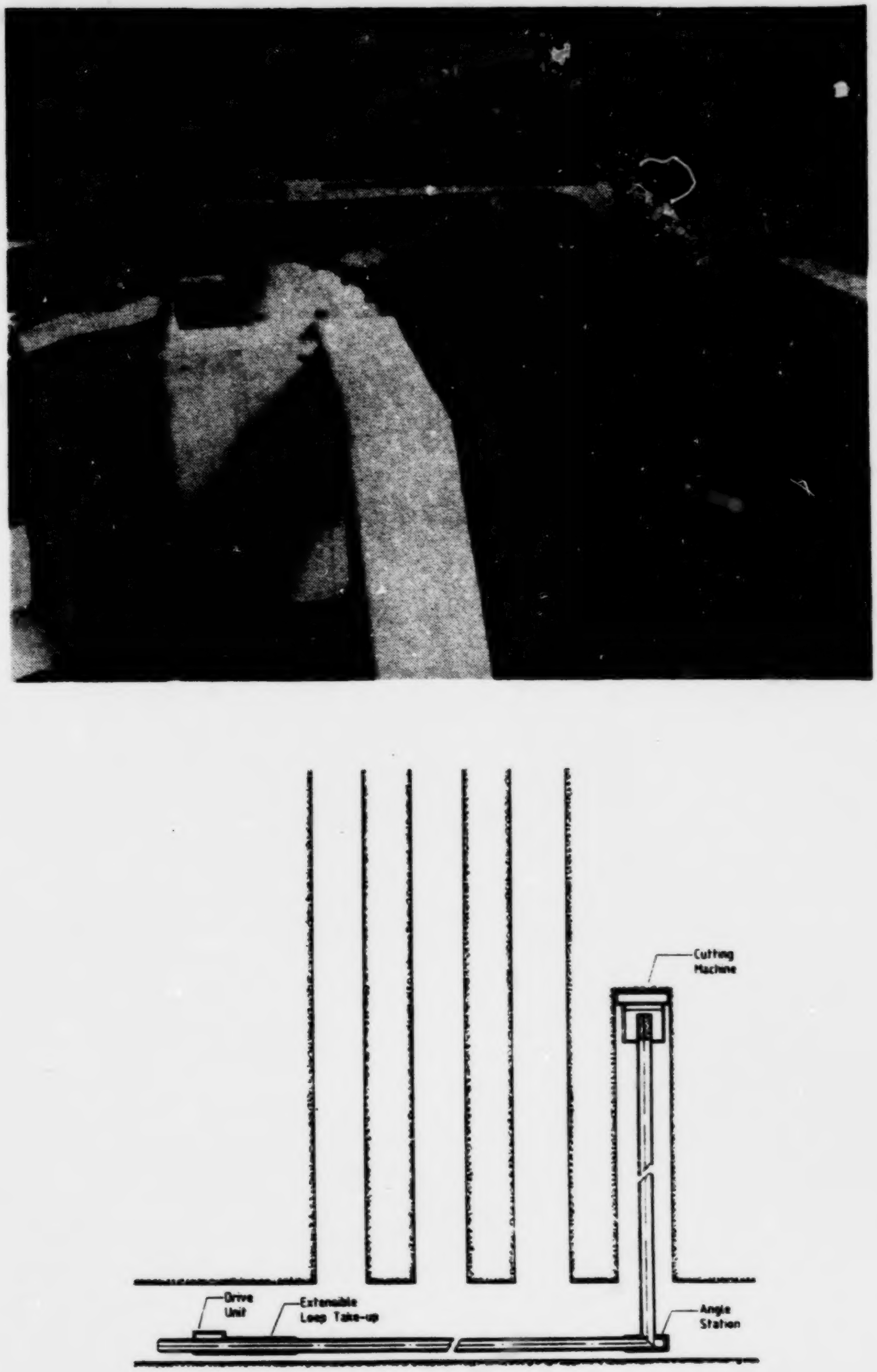
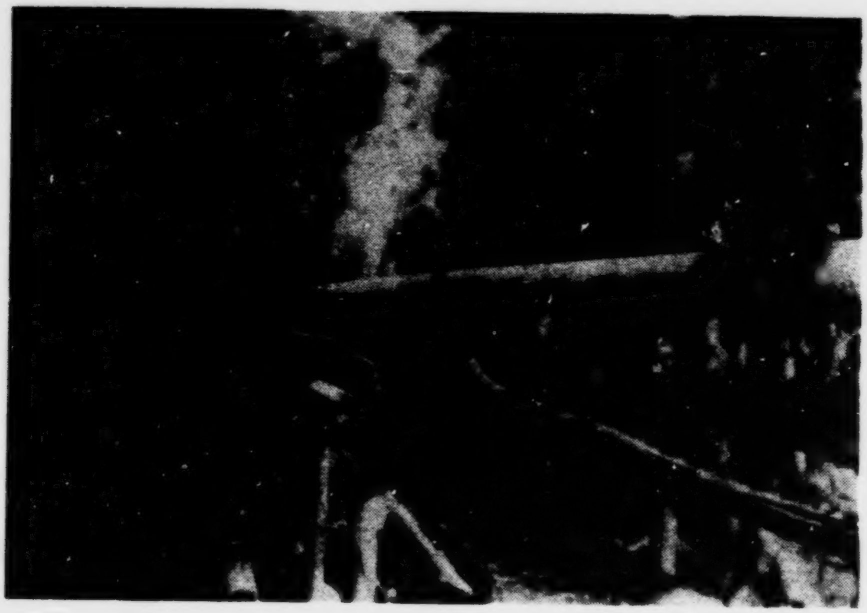


FIGURE 5-1 CONVEYOR ANGLE STATION (120kW)



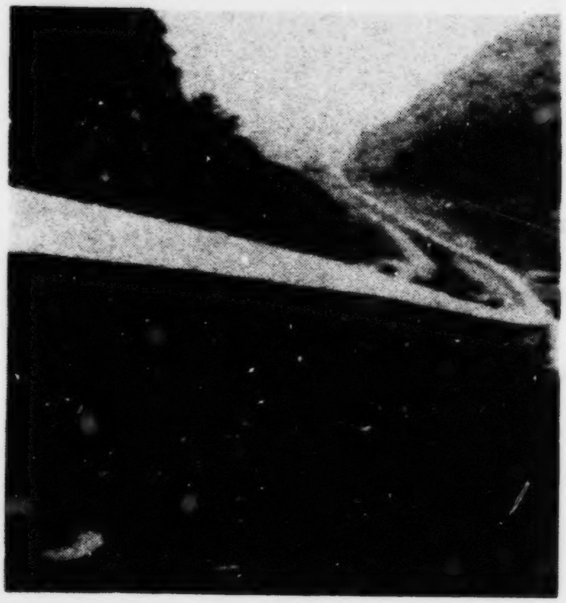


FIGURE 5-2 CURVED BELT CONVEYOR IN SURFACE AND UNDERGROUND SITUATIONS

522 MULTIPLE FLIGHT CONVEYORS

It is readily evident that with the present level of technology, the change of direction in the primary conveyor transport system is best accommodated by a transfer point which may or may not incorporate a bunker.

.1 Initial Leg - 3 000 km Long, 725 m Lift (14°)

a) Cable Belt

Due to limitations on the maximum diameter of cable which can be used (57 mm) the cable belt cannot handle more than 1900 tph over the length and lift specified for this leg.

Two alternatives are possible to increase the effective capacity to 2 400 tph using cable belts. These are (1) Twin conveyors of 1 200 tph capacity; and (2) Using a strata bunker to buffer the flow from the 2 400 tph second leg belt conveyor.

i) Twin Conveyors

The single 1300 mm wide 1 900 tph conveyor would be replaced by two parallel conveyors, 950 mm wide, each handling 1 200 tph, the belt speed remaining the same. The power required would be 2 x 3050 kW or 6100 kW in total compared with 4560 kW for the lesser rated single conveyor.

The advantages of this system are that:

1. Capacity requirements are met
2. Failure of one drive unit does not shut the system down
3. Both drive units are on the surface

The disadvantages are:

1. Two conveyors are required with more complicated installation, monitoring and control, and maintenance
2. Capital costs are increased by approximately 20%
3. Operating costs will be marginally (5%) higher

ii) Surge Bunker

Since the single flight high lift conveyor is limited to 1900 tph, but the second leg conveyor is able to deliver 2400 tph, the provision of a strata bunker of approximately 8000 tonnes capacity will enable the difference in conveyor capacities to be handled.

If the normal operational period for coal clearance is say 16 hours, then the operation of the high lift conveyor for a further 4 hours would enable the output to be handled. The respective capacities of the conveyors in tonnes per day being:

- 2400 tph conveyor (16 hrs) - 38,400 tpd
- 1900 tph conveyor (20 hrs) - 38,000 tpd

The advantages of the system are:

1. Capacity requirements are met with a single flight conveyor
2. Surge capacity is buit into the system
3. Control and monitoring simplified
4. Depending on strata conditions, the strata bunker may be a lower capital cost than the additional cost of the second conveyor

The disadvantages are:

1. A very large excavation (8 800 m^3) would be required
2. Access in steep seams may be difficult, but the use of the high angled sandwich conveyor may solve this problem (Fig. 5-3).

(b) Steel Cord Belt

The steel cord belt has no difficulty in meeting the requirement for 2400 tph this high lift leg using ST 7000 steel cord belting. The power required at a belt speed of 3.8 metres per second is 6 700 kW.

(c) Booster Drives

With the standard PVC solid woven fabric belt, type 15, the maximum power which can be transmitted in these conditions is approximately 1200 kW with a 9:1 safety factor. At a belt-speed of 3.8 m/sec and with a belt width of 1400 mm, the system would require a head end drive unit of 1200 kW and four booster drives (each of 1200 kW) distributed along the length of three kilometres.

One problem which arises with booster conveyors of this level of drive power is that the length of a 1200 kW

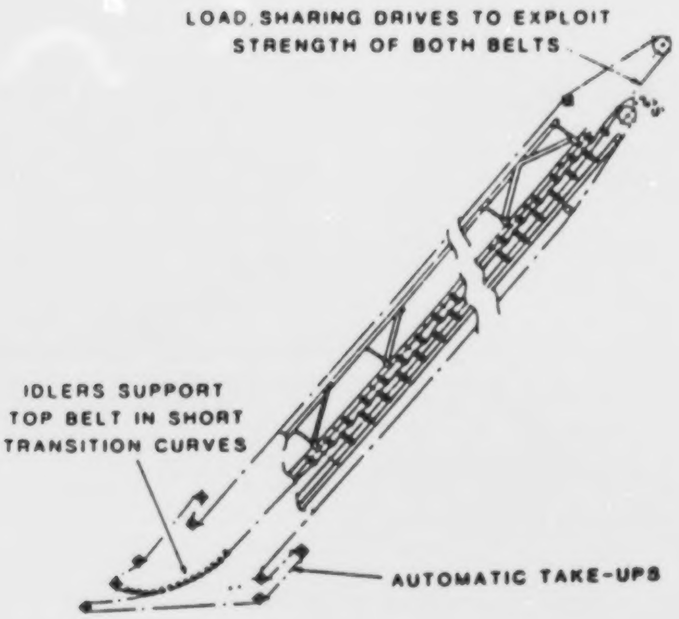

LOAD SHARING DRIVES TO EXPLOIT STRENGTH OF BOTH BELTS
IDLERS SUPPORT TOP BELT IN SHORT TRANSITION CURVES
AUTOMATIC TAKE-UPS

FIGURE 5-3 MECHANICALLY PRESSED SANDWICH CONVEYOR FOR VERY STEEP ANGLES

booster conveyor will be of the order of 800 - 900 metres in order that the drive power can be transmitted. Four such drives thus approaches the available length of the main conveyor. It is, therefore, likely that this method may be impractical.

If steel cord belting is used with the booster drive system, to enable a lower specification steel cord belt to be used (ST4000), then the maximum power which can be transmitted at a factor of safety of 6:1 is of the order of 2600 kW. The system could therefore be operated with a 2400 kW head end drive plus two booster drives at 2200 kW. The decision would depend on whether the saving on belt cost would be sufficient to offset the extra cost of the two booster drives and their controls.

Similarly for the steel cord booster conveyor, however, available main conveyor length may be insufficient to incorporate the two booster conveyors.

If Kevlar 49 is used, the results approach those given for the steel cord belt, but the same length problems still apply.

(d) Conclusion

When considering a high lift, high tonnage conveyor at 2400 tph, the steel cord belt conveyor is the only suitable candidate and even that will be operating at the limit of belt strength.

If a more realistic tonnage figure of say 1850 tph is used, then both the cable belt and steel cord belt conveyors are capable of carrying the output over the distance and gradient.

With the advantage of being able to locate the drive units on the surface for either of these two systems, we do not consider booster conveyors to be attractive for this initial leg of the system by virtue of the complications of additional drives and control and the lack of length to incorporate the booster drives. However, such a decision should be made on the basis of all factors including economics. A comparison at this level falls outside the scope of this study.

.2 Second (Dip) Leg - 7 000 m, 175 m lift, 2500 tph

(a) Cable Belt

The cable belt is capable of handling these criteria in either of two ways. (i) with an underground drive at the change of direction or (ii) with the drive at the surface.

i) Underground Drive

The belt would require to be 1300 mm wide, travelling at 4.3 m/sec using 2450 kW at full load.

The disadvantages with this method are that a large excavation is required at the transfer point to accommodate the cable belt drive unit, the operation of changing the cables becomes more complex, and heat loss from the drive may present a ventilation problem.

ii) Surface Drive

It is feasible to locate the drive for the second leg cable belt on the surface adjacent to the initial leg, drive, passing the cables down the drift above the first cable belt. The cables are then deflected into their proper path at the transfer point. Belt width, speed and specification remain the same as for the underground drive but the power required increases by 12% to 2750 kW due to cable losses in the first drift and in the deflector pulleys. The capital cost of the conveyor is increased by about 8%.

The advantages of this system are:

1. Drive unit located on the surface
2. Flame proof electrics not required
3. Large underground excavaions not required
4. No heat loss/ventilation problems
5. Control and starting much simpler

The disadvantages are:

1. Need for deflector pulleys at transfer point
2. Possible layout complications on surface
3. Uses longer cables, more splices, more maintenance
4. Need to support cables in first drift

(b) Steel Cord Belt

The steel cord belt conveyor has adequate capacity to convey the requisite tonnage over the length and lift specified. This can be achieved by using a 1400 mm belt running at 3.8 metres per second requiring 3900 kW. The belt would be ST7000 with a 7:1 safety factor. If a wider belt is required, say 1800 mm, the speed drops to 2.54 metres/second, the power required to 3700 kW. The belt remains at type ST7000 but the safety factor drops to 6.4:1.

(c) Booster Conveyors

For the fabric belt (PVC) to be utilised, with a safety factor of 9:1, and to keep the number of drives to a minimum type 12 belt will allow a 1200 kW head end drive to be used with two 1200 kW booster drives along the length of the conveyor, the belt width and speed being 1400 mm and 3.8 m/sec. respectively.

In a similar manner as used for the first leg, booster drives can be used with steel cord belting to reduce the specification of the belt. A 2000 kW drive head with a 2000 kW booster drive operating with the same belt speed and width, would allow type ST4000 belt to be used instead of type ST7000.

(d) Conclusions

When one considers that the second or dip belt will be continually extended during its life, the ability to vary the power during the life of the conveyor is a distinct advantage.

In this respect, the booster drive has considerable advantages since the conveyor can commence operations with the drive unit only and have the booster drives added when required.

If the cable belt and steel cord belt drives are multi-motor drives, it may be possible to start operations with say two motor drives and add the others as demand dictates. This does not however overcome the need for large excavations for the steel cord belt and the cable belt drives assuming that the cable belt drive is not placed on the surface.

523 MAXIMUM PERFORMANCE

.1 First Leg

Based on carrying coal over a distance of 3000 metres through a vertical lift of 725 metres; the limiting performances of the various belt types are:

	Cable Belt	Steel Cord	Booster Drives
Belt width (mm)	1300	1800	1400
Belt speed (m/sec)	4.3	3.8	3.8
Belt type	Cable Belt	ST7000	15
Safety factor (belt)	-	6.0	9.0
Max. power (kW)	4600	6700	*
Capacity (tph)	1900	2600	*

* Limit set by number of booster drives it is practical and economical to install. At these power levels it may not be possible to install four booster drives in the roadway length. Insufficient data is available to determine the critical lengths and powers.

.2 Second Leg

Based on carrying coal over a distance of 7,000 metres through a vertical lift of 175 metres, the limiting performances of the various belt types are:

	Cable Belt	Steel Cord	Booster Devices
Belt width (mm)	1800	1400	1400
Belt speed (m/sec)	4.3	4.3	4.3
Belt type	Cable Belt	ST7000	15
Safety factor (belt)	-	7.0	10.0
Max. power (kW)	4600	4800	6000*
Capacity (tph)	3900	3000	3800*

* Assuming booster conveyors occupy all the available length (maximum of four booster drives).

From these figures, it can seem that the requirement of 2400 tph on this leg is well within the capabilities of the systems although it is unlikely that the booster drive system would be operated with the full length of the main conveyor boosted.

524 SYSTEM SELECTION

Table 5-3 lists the main characteristics for each of the three conveyor systems. Many of these comparisons are broad and subjective and can only be made objective when the systems are designed for a specific installation.

It is therefore not practical to try and evaluate the three systems more precisely to arrive at the most suitable system.

However, on the basis of the data provided in the report, it does appear that the choice of conveyor for each leg is limited to:

(a) First Leg (2400 tph)

1. Steel Cord Belt Conveyor
2. If the capacity is reduced to 1900 tph then the cable belt conveyor becomes a candidate

(b) Second Leg (2400 tph)

All three systems - cable belt, steel cord belt, fabric belt with booster drives - are applicable

5.3 PRIMARY SYSTEMS - SLURRY PUMPING

In the discussions in Part 4, the only hydraulic transportation system which showed capabilities for handling the tonnages, over the length and lift required, was the slurry pumping system.

No single slurry pump or pipeline has the capacity to meet the requirements, but by using parallel systems of pumps and pipelines, the requisite output could be handled.

However, as far as we are aware, no mine has yet operated a slurry pumping system at 2400 tph over 10,000 metres with a 900 m lift.

The maximum throughputs achieved to date are 1200 tph, and the maximum lifts with a single pump (at a lower tonnage rate) are 400 m.

Calculations indicate that the total power required to pump 1750 tph over 10,000 m through a lift of 1000 m is 11,200 kW (Figure 5-4) and that this increases to 17,850 kW if the output is raised to 3000 tph (Figure 5-5).

TABLE 5-3

Conveyor Data Comparison
(in Relation to Scope Conditions)

Item	Cable Belt	Steel Cord Belt	Booster Drives
Technology	Well Proven	Well Proven	Well Proven
Application	World Wide	World Wide	World Wide
Capital Cost Index	1.20	1.35	1.00
Operating Cost Index	1.00	1.04	1.06
Belting	Special	Special	Standard
Belting Cost Index	1.50	1.60	1.00
Belt Life (yrs.)	10-12	7-8	2-3
Belt Safety Factors		7:1	10:1
Belt Tension	Low	High	Average
Belt Weight	High	High	Average
Belt Elongation	0.4%	0.3%	3-4%
Belt Splicing	Complex	Complex	Simple
Joint Efficiency	90%	100%	70-80%
Drive Units	Single High HP	Single High HP	Multiple Lower HP
Drive Components	Massive Special	Massive Special	Average Standard
Structure	Special	Standard	Standard
Belt-Tension Arrangements	Complex	Simple	Simple
Starting	Simple	Simple	Complex
Control	Simple	Simple	Complex
Underground Drive Excavation	Extensive	Extensive	Minimal

TABLE 5-3 (Cont'd)

Item	Cable Belt	Steel Cord Belt	Booster Drives
Foundations (Including Drive House)	Complex	Complex	Complex
Ability to Extend Length	Fair	Complex	Good
Effect of Drive Failure	Shutdown	Shutdown	Reduced Capacity
Ability to turn coners in single flight	Yes, but complex	No	No
Heat Generation at Drive Heads	High	High	Low
Variable Speed	Easy	Easy	Difficult
Corrosion Resistance	Low	Medium	High
Power Cost Index	1.0	1.43	1.18
Availability (%)	99	99	92-98
Maintenance	Average	Minimal	Continuous

In the first case, two 483 mm pipelines are necessary, and in the second case, three 546 mm pipelines are necessary. However, the use of such systems would represent a big leap forward in technology and this, taken with the problem of the location of the sump and slurry pumping station, indicate that the system cannot be considered as a candidate for the underground mines.

5.4 SECONDARY SYSTEMS

541 SELECTION

Whilst it has been shown in Part 4.1 that the only suitable systems are belt conveyors or hydraulic transport systems, the prime factor in the selection of a secondary system must be its compatibility with the primary transport system.

Since the only suitable primary system is the belt conveyor, then the only suitable practical system for secondary haulage must also be the belt conveyor.

There are four types of conveyor which meet the selection criteria.

i) Conventional fabric belts without boosters

ii) Conventional fabric belts with boosters

iii) Steel cord belts

iv) Cable belts

When consideration is taken of the need to continually lengthen or shorten the belt length of the secondary conveyor as the mining district advances or retreats, then as neither the steel cord belt nor the cable belt are capable of easy length adjustment, since they would also be vastly overrated for belt specification, and since there is the need for the special return wheel and drive unit arrangements for the cable belt, neither system qualifies as a candidate.

Conventional belts with or without booster drives, dependent on the lengths and gradients, are capable of meeting the requirements, though the use of a booster drive would add considerably to the delays to the face operations when it has to be added to or removed from the system.

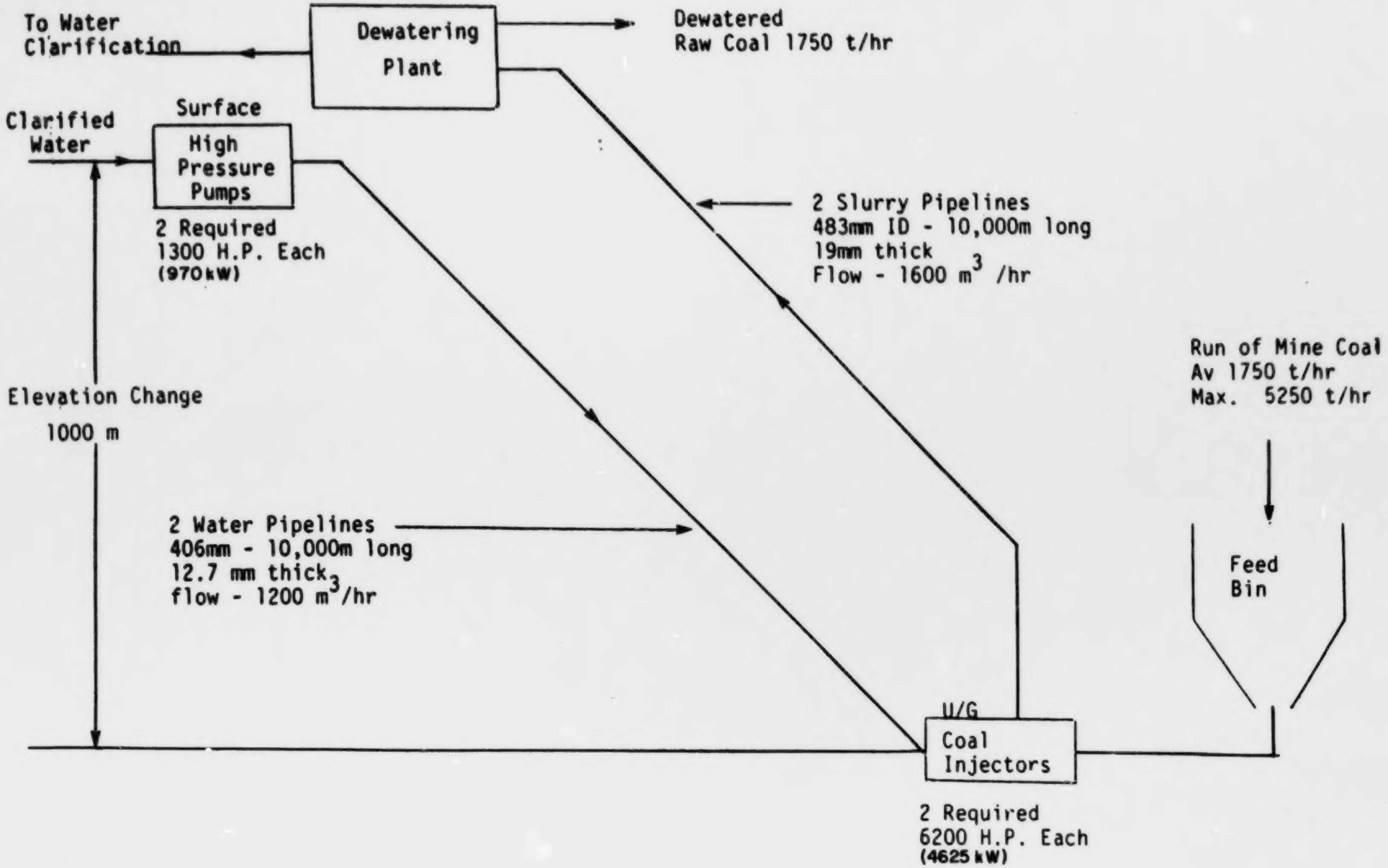


FIGURE 5-4 SCHEMATIC SLURRY PUMPING STATION SYSTEM - 1750tph

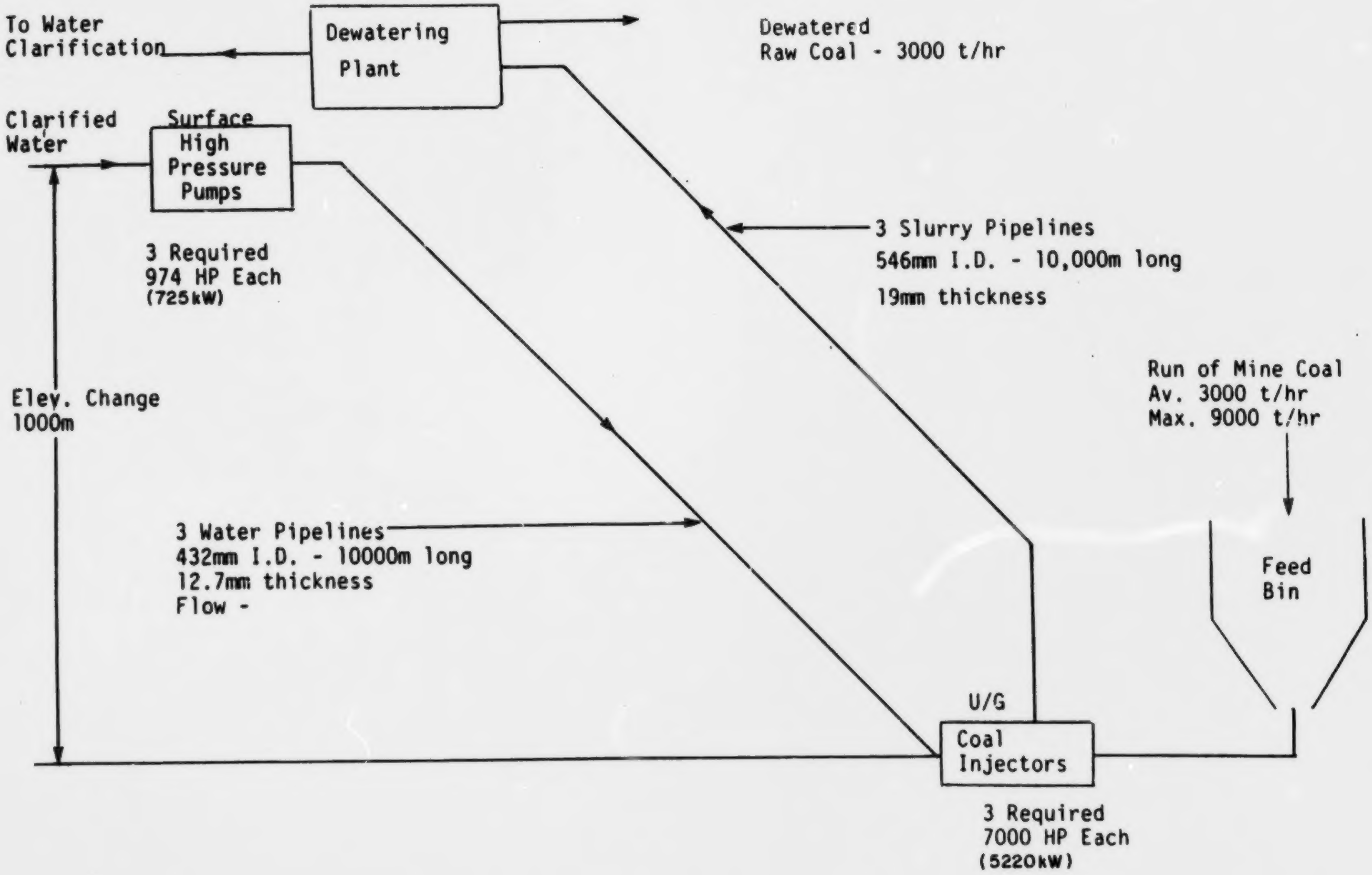


FIGURE 5-5 SCHEMATIC SLURRY PUMPING SYSTEM 3000tph

542 MAXIMUM PERFORMANCE

.1 PVC Solid Woven Belt

(a) Using the highest grade of PVC solid woven fabric belt currently available, the type 15 with a minimum warp strength of 2687 kg/cm, the maximum performances for the secondary belt conveyors handling coal at 600 tph are listed below.

1. Belt of 1050 mm width running at 1.8 metres per second
2. Maximum power transmitted 380 kW at 10:1 safety factor
3. Maximum horizontal distance at zero grade is 4464 metres
4. Maximum vertical lift over 2000 m length is 130 metres or a gradient of 6.5%

(b) A stronger PVC belt, type 20 with a minimum warp strength of 3582 kg/cm will shortly be available. This would raise the above figures to:

1. Maximum power at 10:1 safety factor 500 kW
2. Maximum horizontal length at zero grade 5950 metres
3. Maximum vertical lift over 2000 metres length 190 metres (9.5%)

(c) If the new Kevlar 49 Belt is used which has a minimum warp strength of 4000 kg/cm, and retaining the same 10:1 safety factor because of low joint efficiencies, the limiting factors become:

1. Maximum power 560 kW
2. Maximum horizontal distance 6640 metres
3. Maximum vertical lift 230 m (11.5%)

PART 6

CONCLUSIONS

PART 6 - CONCLUSIONS

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6.0 CONCLUSIONS

This study has reviewed the various methods in use for transporting coal and waste underground. These included rope haulage, locomotive haulage, belt conveyors, the use of trackless vehicles, and hydraulic and pneumatic transportation systems.

The review examined the capabilities of each system for two requirements. First, for secondary haulage systems at 600 tph and second, for primary haulage systems at 2400 tph.

As a result of these reviews, we have reached the following conclusions.

6.1 PRIMARY TRANSPORTATION SYSTEMS

1. None of the systems reviewed is capable of handling, in a single flight, a tonnage of 2400 tph over a distance of ten kilometres through a vertical lift of 900 metres.

2. The following systems are not able to handle the tonnage requirement (2400 tph).

   - rope haulages in any form
   - compressed air and rack locomotive haulages
   - airlift and hydrohoist systems
   - pneumatic systems
   - trackless systems

3. The following systems cannot meet the distance requirement (10 km).

   - battery and compressed air locomotives
   - direct and main and tail rope haulages
   - airlifts and hydrohoists
   - pneumatic systems

4. The following systems cannot meet the gradient requirement (25%).

   - locomotives
   - trackless vehicles
   - gravity slurry systems (positive gradient)

5. The only system capable of meeting the requirement to operate through a 45° bend, without a transfer station is the cable

belt system through the use of an angle station. Angle stations are being developed for fabric belt conveyors, but, to date, are only available for the low powered drives (120 kW).

6. For the three km leg from the surface, the only practical system at 2400 tph is the steel cord conveyor. The maximum capacity of a cable belt for these conditions is 1900 tph. Booster conveyors are not practical since they would have to occupy almost the total length of the roadway.

7. The demands of the first leg at 2400 tph, 3000 m long, lift 725 m, are at the limits of present technology for belt conveyors.

8. The requirement for a capacity of 2400 tph represents an annual mine capacity well in excess of eight million tonnes per year. We believe that this is too high. A figure of 1800 tph would be more practical.

9. Slurry pumping systems are not suitable because they would require either pumps in series and parallel, or larger horsepower pumps than are currently in use. A leap forward in technology is required to meet the requirements.

10. For the second leg, any of the three belt conveyor systems are suitable. With the cable belt system, the drive could be put on the surface.

11. Surge capacity for the primary systems is best accommodated with mechanical, roadway or strata bunkers, located preferably at transfer points or at changes of direction.

12. When properly installed and maintained, conveyors offer excellent reliability.

13. Developments in monitoring and control ensure that conveyor systems are much safer, easier to automate and to operate from a remote control station on the mine surface.

14. Detailed comparison and ranking of systems must be related to site specific conditions, layouts, loading point locations, and feed rates. They cannot be developed in this study.

15. The use of curved conveyors may be of interest if mine layout permits, for coping with changes of direction of less than ninety degrees.

6.2 SECONDARY TRANSPORTATION SYSTEMS

1. The applicable systems are belt conveyors and hydraulic haulage.

2. The secondary transport system must be compatible with the primary system.

3. The steel cord and cable belt systems are not suitable because of overspecification and the need to keep altering the length of the conveyor.

4. Conventional fabric or kevlar solid woven conveyor belts are the most suitable system.

TABLE 6-1

Advantages and Disadvantages of each of the Conveyor Belt Systems
(Assuming two booster conveyor and three calbe or steel cord belts required)

Item	Steel Cord Belt	Cable Belt	Booster Belt
Technology	well proven	well proven	well proven
Application	wide	Limited	Wide
Drive	Single-Massive	Single-Massive	Multiple-Normal Size
Belting	Special-High Cost	Special-High Cost	Normal-Cost approx. 45% of calbe and steel belts
Maintenance Cost	Low	Medium	Medium
Power Costs (start-up power damand)	High	High	Low
Power Costs Overall	High	Medium	Medium
Ability to turn the 45° with ore belt	No	No	No
Size of Drive for Secondary Conveyor	Massive	Massive	Normal
Heat Dispersion from UG Drives	High	High	Normal
Electrical Equipment - Surface	Standard High Voltage	Standard High Voltage	Standard High Voltage
- Underground	Special High Voltage	Special High Voltage	Standard Voltage
Conveyor Belt Tension	Very High	Low	Medium
Conveyor Belt Dead Weight	High	High	Normal
Effect of a Failure on one Drive	Belt Shutdown	Belt Shutdown	Reduced Output
Belt Splicing/Cost/Frequency	Difficult/Costly/Infrequent	Difficult/Costly	Simple/Low Cost
			Normal
Individual Components	Very Large and Heavy	Very Large and Heavy	Medium Size & Weight
Exavations required for U.G. Drive	Very Large	Very Large	Small/Minimal
Ability to Extend the Length or Increase Capacity	Poor	Poor	Excellent
Cost of Conveyor Belt Itself	65% of Total Cost	Unknown	40% of Total Cost

PART 7

RECOMMENDATIONS

7.0 RECOMMENDATIONS

1. A determination should be made of the capacity in tonnes per hour for the primary system which can be accepted as being realistic.

2. A study should be made of the detailed characteristics of the three conveyor systems (cable belt, steel cord belt, and solid woven belt conveyors) related to specific mine layouts, gradients, tonnages, and feed rates and locations, to enable a realistic comparison to be made, and the most suitable system selected.

3. The potential for the use of curved conveyors and angle stations on high horsepower conveyors should be investigated.

4. The merits of the different forms of surge bunkerage (mechanical, roadway and strata) should be investigated.

APPENDIX A

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APPENDIX B

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HIGH CAPACITY, LOW COST CONVEYOR INSTALLATIONS - THE LINEAR DRIVE ROUTE

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ABSTRACT

The most costly item in any conveyor installation is the conveyor belting, yet to increase the capacity of an installation the power applied to it must increase which, in turn, results in increasing the specification and cost of the largest cost item of any installation. This paper discusses how, through the application of Linear Conveyor Drive Units to Belt Conveyors, the capacity of an installation can be increased by the use of increased power applied to the conveyor, yet the belt remains the same without any reduction in the safety factors or the life of the belt. It also shows how it can be applied to new installations to reduce the capital cost by as much as 30%, as well as being used to uprate an existing installation by as much as 100%, with the use of extremely small amounts of additional equipment. References are made to existing installations.

KEYWORDS

Belt, Conveyors, Linear, Cost, New, Existing.

INTRODUCTION

Expansion in the mining industry has called for an ever increasing handling of bulk materials, both in terms of capacity and distance transported. This demand has stimulated continuous technological advances in the design of belt conveyors and has led to today's large capacity, underground conveyors capable of lengths and lifts that eliminate transfer points.

Two major developments have taken place to permit this. The first is the improvement in belt strength through higher strength fabric belts, and, for yet higher powered conveyors, steel cord belts. The second is the development of the linear drive or booster conveyor which permits power to be added along the length of the conveyor so requiring belting of a strength commensurate with the individual power units but giving the overall performance of a single flight conveyor.

This paper examines these developments and shows how this large increase in capacity has been achieved in such a way that the size to power ratio has been minimised, at the same time maintaining all the simplicity of operation in an installation of the familiar low capacity belt conveyors.

FIGURE 1

FABRIC - SOLID WOVEN

TYPE	MIN.WARP STRENGTH LBS/INCH	KG/CM	APP.MIN. WEIGHT KG/M²	THICKNESS MM	DRIVING DRUM DIAMETER	ELONGATION AT BREAK
6	6500	1160	14.75	12	630mm)	15% to 30%
8	8000	1430	15.30	13.5	760mm)	
10	10000	1790	18.58	14.5	800mm)	
12	12000	2150	19.13	15.0	1000mm)	
15	15000	2687	20.00	15.5	1250mm)	
20	20000*	3582				

STEEL CORD
ST NUMBER x (APP.MIN. BK STRENGTH Kg/Cm)

TYPE	MIN.WARP STRENGTH KG/CM	APP.MIN. WEIGHT KG/M²	APP.MIN. THICKNESS MM	DRIVING DRUM DIAMETER	ELONGATION AT BREAK
1150	1150	20.5	14	630mm)	2.0 to 3.0%
1400	1400	22.5	15	800mm)	
1600	1600	23.5	15.3	800mm)	
2000	2000	24.5	15.6	800mm)	
2500	2500	29.4	17	1000mm)	
3500	3500	39.0	22	1400mm)	
4000	4000	42.6	23	1400mm)	

BASED ON BELT SPEED OF 2.5 m/s 1000 mm WIDE BELT $HP \propto \frac{SPEED}{2.5}$

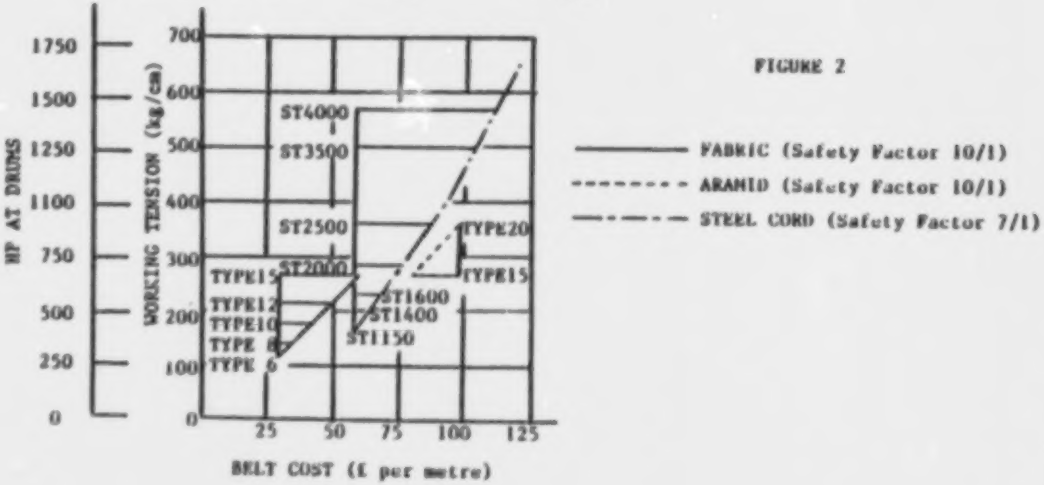


FIGURE 2

The overall result has been to produce an extremely "pit worthy" piece of equipment that is highly competitive with other designs of conveyor, yet has the advantage of great reliability and because of its compact size, minimises extra mining costs.

BELT DEVELOPMENTS

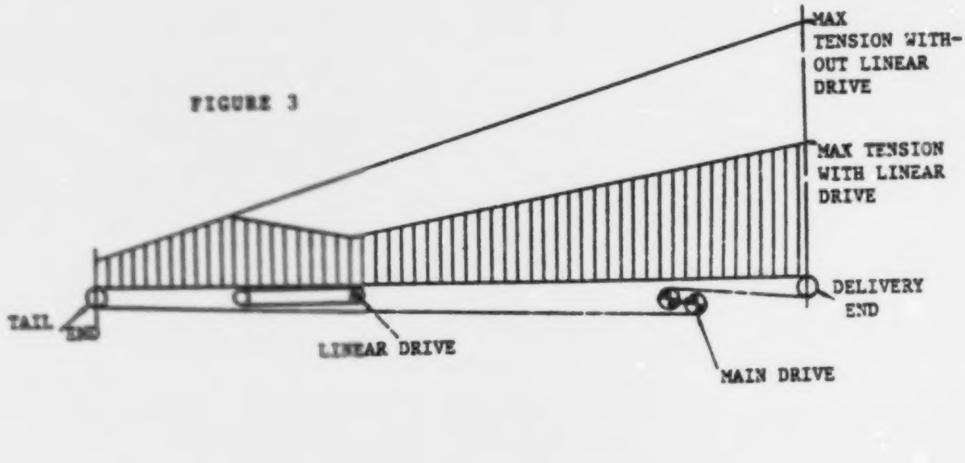
To appraise the cost effectiveness of linear drives in minimising belting specification and cost, we need a technical and cost base. The comparative physical characteristics of fabric and steel cord belting are given in Fig.1, whilst Fig.2 compares the belt cost of various grades for a given belt width.

In a majority of applications, power is applied to the conveyor at the head end which means that the tractive force to motivate the entire belt system is imparted to the belt at a single point and the tensile strength of the belting needs to be rated accordingly. The head end drive powers for fabric or steel cord belts, at a width of 1000 mm (40") and at a belt speed of 2.5 metres per second (approximately 500 ft. per minute), are shown in Fig.2. They are directly proportional to belt speed and width.

For a belt 1000 mm (40") wide, the drum power ranges from 300 H.P. (223 kW) for a type 6 fabric belt to 1400 H.P. (1044 kW) for steel cord ST.4000. The fabric belt figures are based upon a factor of safety of 10 to 1, and for the steel cord belt a factor of safety of 7 to 1. The difference is due to the greater strength and fatigue life of the joint of steel cord belts. On well engineered systems using the appropriate control factors to limit the acceleration load, the factor of safety can be reduced to 8 to 1 for fabric and 6 to 1 or below for steel cord belts, which will increase the power that can be transmitted by any one belt.

If linear drives are employed, where power is added along the conveyor length thus reducing the belt tension (Fig.3) but retaining the same factor of safety, then from Fig.2 the belting specification and cost can be established and compared with that required for a conveyor with head drive. For example, a conveyor with a head drive of 900 horsepower drum using 1000 mm wide belt running at 2.5 m/sec would require steel cord belting ST2500 at a cost per metre of £83. Alternatively the same conveyor having linear drives, each of 300 drum horsepower would require type 8 fabric belt at a cost per metre of £35, a belting cost reduction of 57%.

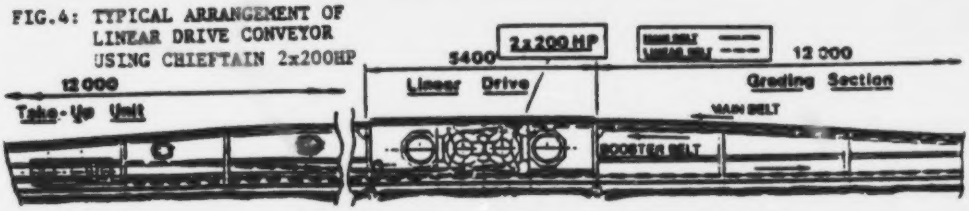
FIGURE 3


MAX TENSION WITH-OUT LINEAR DRIVE
MAX TENSION WITH LINEAR DRIVE
TAIL END
LINEAR DRIVE
MAIN DRIVE
DELIVERY END

LINEAR DRIVES

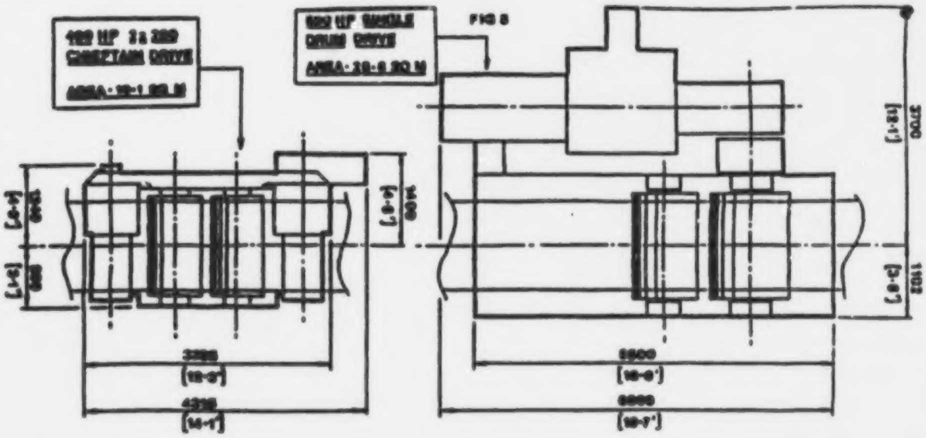
Development In contrast to the conventional mode of power transference in a conveyor by wrapping the belt around a single or series of driving drums, the linear drive transmits the tractive force linearally by frictional contact with the main belt. The power transmitting element is an endless driving belt which is in contact with the underside of the main belt as shown in Fig.4.

FIG.4: TYPICAL ARRANGEMENT OF LINEAR DRIVE CONVEYOR USING CHIEFTAIN 2x200HP



This simple method of power transferring, which does not disturb the carrying surface of the belt, enables the principle of intermediate drives to be applied in a conveyor system without the problem of transfer points or tripper type drives. The resulting belt tension diagram compared with that of a head end only drive conveyor is shown in Fig.3 and indicates the lower maximum belt tension when a linear drive is used.

The use of linear drives means that a high power, long length conveyor can be constructed as the sum of many little conveyors to give the operational simplicity and convenience of a high power single flight system. At the same time the engineering and size problems are reduced to those of a small conveyor of the size of the individual linear drive modules. The lower belt tensions permit yet smaller machinery to be used and the design can be so structured as to make use of standard mining drives, designed to minimise excess mining excavations. Fig.5 shows a 600/700 H.P. belt drive using proprietary gearboxes compared with a standard drive of 400/500 H.P. using gearboxes specifically designed for use in mines. The result is a drive width reduction of 54%, and a reduction in overall drive area of 64%.



The concept of using a linear drive system and developing what from an operational standpoint is a single flight, high horsepower conveyor, but is from engineering appearances a collection of common mining conveyors, not only has major effects on the engineering of a new belt system but additionally the capacity of existing conveyors can be increased by increasing the power, but leaving the belting and the existing drives alone and merely adding Linear drives for the additional power.

When this situation has arisen in the past the only solution has been to change the characteristics of the conveyor by changing the belt to a type with a high tensile strength and to install a new conveyor drive of sufficient horsepower to meet the new conditions. This traditional solution involves major capital expenditure in conveyor belts drives together with excavations to accomodate the larger head drive unit.

Testing and Calculations Dowty Meco have always been in the forefront of development and have pioneered many original concepts which are now accepted as standard conveyor engineering practice.

The advantages of linear drives were recognised some 7 to 8 years ago. In order to evaluate the factors effecting their performance, static and dynamic test rigs were built from which the apparent coefficient of friction between belts was established. This testing involved a multiplicity of conditions such as:- Different types of conveyor belting covers (i.e. PVC, nitrile, neoprene, rubber); covers in different conditions (i.e. new, worn, dry, wet, slimy, etc); idlers of various troughing angles and spacing; varying main belt and linear belt tensions; pressure between conveyor belts etc. Subsequently further research was done to confirm our findings, mainly because the limiting coefficient of friction between compressible surfaces depends upon pressure, temperature and differential velocity. The resulting envelope of results enabled us to go forward with confidence into our first linear drive installation in 1978.

Practice. Fig.6 details the Dowty Meco linear drive applications operating with the National Coal Board and in Spain, U.S.A., and Sicily. The applications range from 300 H.P. to 1400 H.P.

FIG.6

Installation	A	B4	FW	L	E2	WE	E8	E9
Date commissioned	6.78	12.78	4.78	5.79	8.79	9.79	5.80	3.81
Conveyor length (ft)	[illegible]	5910	4884	[illegible]	3285	7128	6440	7520
Conveyor lift (ft)	187	170	[illegible]	14	283	219	75	86
Belt width (in)/Type	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Speed (ft/min)	[illegible]	[illegible]	420	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tonnage/hour	[illegible]	[illegible]	400	[illegible]	1000	[illegible]	[illegible]	1000
Total motor (hp)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Head drive type	[illegible]	2408	2408	2408	2408	2408	[illegible]	[illegible]
Head motors (hp)	240	[illegible]	300	240	[illegible]	300	3x120	3x120
No. of linear drives	1	1	2	1	1	1	1	1

Installation	FW	WH	O	S	D	US	B	I
Date commissioned	1.81	5.81	7.81	7.81	7.81	5.82	5.82	9.82
Conveyor length (ft)	2700	11700	1575	[illegible]	[illegible]	6870	4000	[illegible]
Conveyor lift (ft)	[illegible]	116	[illegible]	[illegible]	120	101	172	[illegible]
Belt width (in)/Type	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Speed (ft/min)	[illegible]	[illegible]	525	[illegible]	[illegible]	500	420	[illegible]
Tonnage/hour	1200	[illegible]	[illegible]	[illegible]	[illegible]	1100	[illegible]	[illegible]
Total motor (hp)	[illegible]	300	[illegible]	750	300	510	[illegible]	[illegible]
Head drive type	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2408	[illegible]	2408
Head motors (hp)	3x150	2x75	2x150	3x125	1x180	3x120	2x150	2x200
No. of linear drives	1	1	1	1	1	1	1	1

Effects on Conveyor Design. The benefits of linear drives have the following effects on conveyor design:-

(i) The use of small purpose designed drive units eliminates extra mining operations for their installation. (ii) Ease of shipment inbye when access to a new district is restricted by old or small roadways. (iii) It enables the use of low strength low weight conveyor belting, with reduced capital and replacement costs. (iv) Individual conveyors can be made longer at minimum extra cost and inconvenience. (v) Standardisation of the grade and type of conveyor belting used in the mine regardless of the total installed driving power. (vi) Belt speeds can be kept relatively low, so enabling longer distance manriding thus decreasing overall journey time.

In addition to these practical "pitmatic" advantages many application studies have predicted an overall capital cost saving with linear drive systems compared to the conventionally powered belt system. This varies with details of the situation, between 10% to 30% when mechanical, electrical and belting costs are summated.

New Installations. An example of a linear drive belt conveyor, applied to a new installation, is that in Fig.7. The main drift conveyor is 1.7 kilometres long, rising to 184 metres. Initially the system is to deal with 500 tons per hour of kainite rising eventually to 1000 tons per hour. Narrow, high speed belts were recommended with initially a power of 800 H.P. (600 kilowatt) distributed between a 400 H.P. head drive and a 400 H.P. (300 kW) linear drive.

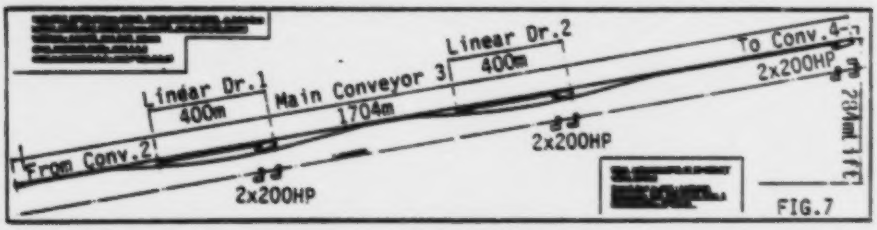


FIG.7

Additional 200 H.P. (150 kW) power packs are added, together with a second linear drive, to attain a final installed power of 1400 H.P. (1050 kW), using a 800 mm wide type 8 fabric belt. Reference to Fig.2 will show that this would have been impossible with a single head drive design.

The overall cost for the linear drive system (mechanicals, belting, electrics, communication and signalling) was £485,000 compared to a conventional head drive and steel cord belt of £582,000; a 16.6% saving. In addition cash flow benefits would accrue from purchasing equipment to suit 500 tons per hour and adding 200 H.P. (150 kW) driving modules, as the tonnage rate increased to the eventual maximum of 1000 tons per hour.

A further example is a 1050 mm wide conveyor, 1750 metres (5740 ft) long on an adverse gradient of 1 in 8.2, to handle 900 tons per hour of run of mine coal, at a speed, limited by manriding to 2.6 metres per second (510 ft. per minute). The comparative costs are :-

1200 HP head drive conveyor (£612,000):- consisting of mechanicals £256,000, electricals £37,000 and steel cord belting £319,000.
1200 HP linear drive conveyor system:- using 3 x 400 HP linear drives (£425,000) consisting of mechanicals £267,000; electricals £53,000 and fabric belting £105,000. Capital saving using the linear drive system £187,000 (30.5%).

Uprating of Conveyors. A colliery trunk conveyor, required its capacity increased from 800 to 1000 tons per hour. A 450 H.P. head drive and type 8 fabric belt was in use. The capacity increase meant a 600 H.P. head drive and type 12 belt, if conventional conveyor practice was followed. A linear drive application recommended by Dowty Meco was accepted, overcoming the high capital outlay for a new drive and belting. The 150 H.P. linear drive cost approximately £44,000 for mechanicals, electrics and belting. It is still in operation, as are four other conveyors similarly uprated.

Also in 1979 a colliery drift conveyor, used for development required its capacity to be increased from 200 to 400 tons per hour. A 300 H.P. head drive and type 8 fabric belt was in use and manriding limited the belt speed to 2.1 metres per second (420 ft. per minute). The capacity increase meant a 600 H.P. head drive and a type 12 belt, with conventional conveyor practice. We proposed two linear drives and these were installed. The total cost was £90,000 for mechanicals, electrics and belting. Subsequently the colliery installed our linear drives for a major drift conveyor of 900 H.P., using 450 H.P. head drive and a 450 H.P. linear drive.

CONCLUSION

We recognise that mining requirements have generated a range of high horsepower belt conveyors providing continuous bulk output facilities, which means larger, heavier and more unwieldly conventional drives than hitherto. In underground mining in particular, this has numerous drawbacks. Recognising this fact and following the world mining demand for less costly solutions, the Dowty Meco Linear Drive System was developed. In application it has been successful, and is now being recognised as a proven, simple, reliable alternative to the conventional approach, as more mining authorities appreciate its benefits.

ABMEC '83
INTERNATIONAL CONFERENCE ON MINES TRANSPORT
UNITED KINGDOM 1983

PAPER 14: BELT CONVEYORS, STEEL CORD OR FABRIC - CONVENTIONAL OR BOOSTER DRIVES.

Author: D.T.Price, Technical Manager Belt Conveyors,
Dowty Meco Ltd.

The Paper discusses the latest developments in fabric and steel cord conveyor belting, showing how this permits highpowered systems to be engineered yet minimizes the size to power ratio of the drums so reducing the excavation work required for installation in a mine. Additionally it highlights the reliability benefits brought about by these belting developments. The Paper goes on to discuss the methods of operation of linear drives, showing how further savings in excavation and increased flexibility in system design are obtained.

Belt Conveyors, Steel Cord or Fabric - Conventional or Booster Drives.

1. INTRODUCTION

2. BELT DEVELOPMENT AND THEIR EFFECTS ON CONVEYOR DESIGN.
   - 2.1. Development
   - 2.2. Effects on Conveyor Design.

3. LINEAR DRIVES AND THEIR EFFECTS ON CONVEYOR DESIGN
   - 3.1. Development
   - 3.2. Effects on Conveyor Design

4. CONCLUSION.

1. INTRODUCTION.

Since the end of the 19th century, when the first troughed belt conveyors were employed in underground applications, but more especially since World War II, expansion in the mining industry has called for ever increasing handling of bulk materials, both in terms of capacity and distance transported. This demand has stimulated continuous technological advances in the design of belt conveyors and has led to today's large capacity, underground conveyors capable of lengths and lifts that eliminate transfer points. Typically in U.K. coal mines the haulage capacity goes up to about 2500 tons per hour for Trunk Belts and between 1000/3000 tons per hour for major drift conveyor installations, which is more than adequate for a mine with an annual output in the 5 to 10 million ton range. Fig.1 App'n list

Presently, in the UK mines, conveyor belts transport daily some 700,000 tons of mineral (90% of all mineral mined), 10,000 tons of materials and 150,000 men. There are some 6000 conveyors in use. The average shaft to face distance is 3.8 kms and is increasing by 2% per annum.

Two major developments have taken place to permit this. The first is the improvement in belt strength through higher strength fabric belts, and, for yet higher powered conveyors, steel cord belts.

The second is the development of the linear drive or booster conveyor which permits power to be added along the length of the conveyor so requiring belting of a strength commensurate with the individual power units but giving the overall performance of a single flight conveyor.

This paper examines these two developments and shows how this large increase in capacity has been achieved in such a way that the size to power ratio has been minimised, at the same time maintaining all the simplicity of operation and installation of the familiar lower capacity belt conveyors.

The overall result has been to produce an extremely "pit worthy" piece of equipment that is highly competitive with other designs of conveyor, yet has the advantage of great reliability and because of its compact size, minimises extra mining excavation costs.

2. BELT DEVELOPMENTS AND THEIR EFFECTS ON CONVEYOR DESIGN.

2.1. Developments

Fig.2 Fig.3 The comparative physical characteristics of fabric andsteel cord belting are given in Fig.2 whilst Fig.3 compares the belt cost of various grades for a given belt width.

Fig.4 The approximate limitations of power and carrying capacity for fabric or steel cord belts, in the width range 900 mm (35.4') to 1600 mm (63"), at a belt speed of 2.5 m/sec (app. 500 '/min), are shown in Fig.4. They are directly proportional to belt speed.

Although belt speeds in the order of 7m/sec (1400'/min) have been used, the typical range is 2.1 m/sec to 4m/sec (420'/min to 800'/min).

For a belt 1400 mm (55") wide, the drum power ranges from 760 HP (567 kW) for a Type 12 fabric belt to 2000 HP (1492 kW) for steel cord ST4000.

The figures for the fabric belts are based upon a factor of safety of 10 to 1 and for the steel cord belts a factor of safety of 7 to 1. The difference is due to the greater strength and fatigue life in the joint of steel cord belts.

On a well engineered system using the appropriate control factors to limit acceleration loads, the factor of safety can be reduced to 8 to 1 for fabric and 6 to 1 or below for steel cord belts, which will increase the power that can be transmitted by any one belt.

These strength improvements have been principally brought about by increasing the density of the number of tensile members in the belt construction rather than their size. By this means, the minimum bending radius on drums, that is consistant wih high fatigue life, is contained at a reasonable figure.

Furthermore the design of conveyor belting impregnates the tensile members with P.V.C./Rubber (Nitrile or Neoprene) and so considerably assists in permitting the use of these minimum drum diameters in two main ways :-

a) Through cushioning the tensile members as they go round pulleys or over rollers, the Hertzian contact stresses, associated with unprotected, highly loaded tensile elements, are reduced.

b) By fully protecting the tensile members from the environment, corrosion is virtually eliminated so reducing loss of strength, due to reduction of cross-section and fretting.

This ability to maintain small pulley diameters, even at the highest tensile points, is the feature that fundamentally makes the belt conveyor so suited to underground mining. It results in three extremely desirable features.

2.2. Effects on Conveyor Design.

(i) The compact size minimises and frequently eliminates the excavation required to fit the conveyor drives, take-ups and tails in the mine roadway.

(ii) The flexibility of the belt allows it to accommodate undulations in the road and so eliminates the need for extremely accurate alignment when setting up which is costly in both time and money and is frequently disturbed by ground movement after installation.

(iii) The relatively small pulley diameters mean that for a given belt speed, the gearbox reduction is moderate. This allows the use of readily available gearboxes up to 6000 kW, whose dependability is well known through frequent use and where spares and servicing are well maintained.

To illustrate these effects reference should be made to the following figures:-

Fig. 5 - Illustrates a 600 HP (448 kW), intermediate type, single drum drive, with remote delivery unit, to be used underground and deal with a run-of-mine coal tonnage rate of 2300 tons/hr. The single drive drum is of [illegible] mm ([illegible]") diameter. Belting used is 1350 mm wide (54") and is of Type 10 construction, solid woven fabric. The belt speed is app. 2.8 m/sec. (560'/min).

Fig. 6 - illustrates a 1200 HP (896 kW), intermediate type, drive unit for use underground. The primary and secondary drive drums are of [illegible] mm ([illegible]") diameter, each driven by 600 HP (448 kW) motors. The belting used is 1050 mm wide (42") and is of steel cord construction, ST3000, fire resistant. The belt speed is app. 2.66 m/sec (532'/min).

Fig. 7 - shows a belt take-up and tensioning system, within the length of conveyor. Integrated in its design are belt clamping and jointing facilities. This eliminates extra mining excavations that would be required for a take up positioned behind the tail end as well as simplifying the transfer point at the tail end.

Fig. 8 - shows a compact tail end and mineral reception point.

Fig. 9 - shows a heavy duty run-of-conveyor section for 1350 mm wide belt (54"), using 168 mm diameter idlers. It is simple in construction, with stools either placed on the roadway floor or suspended from the roof.

3. LINEAR DRIVES AND THEIR EFFECTS ON CONVEYOR DESIGN.

3.1. Development.

Fig.10 In contrast to the conventional mode of power transference in a conveyor by wrapping the belt around a single or series of driving drums, the linear drive transmits the tractive force linerally by frictional contact with the main belt. The power transmitting element is an endless driving belt which is in contact with the underside of the main belt as shown schematically in Fig. 10.

Fig.11 This simple method of power transferring which does not disturb the carrying surface of the belt, enables the principle of intermediate drives to be applied in a belt conveyor system, without the problem of transfer points or tripper type drives. The resulting belt tension diagram compared with that of a head end only drive conveyor is shown in Fig.11 and indicates the lower maximum belt tension when a linear drive is used.

Fig.12 The use of linear drives means that a high power, longlength conveyor can be constructed as the sum of many little conveyors to give the operational simplicity and convenience of a high power single flight system. At the same time the engineering and size problems are reduced to those of a small conveyor of the size of the individual linear drive modules. The lower belt tensions permit yet smaller machinery to be used and the design can be so structured as to make use of standard mining drives, designed to minimise excess mining excavations. Fig.12 shows a 600 HP belt drive benefiting from compact design but using proprietary gearboxes compared with a 400 HP drive using gearboxes specifically designed for use in mines. This concept of using a linear drive system and developing what from an operational standpoint is a single flight, high horsepower conveyor, but is from engineering appearances a collection of common mining conveyors, not only has major effects on the engineering of a new belt system but additionally the capacity of existing conveyors can be increased by increasing the power, but leaving the belting and the existing drives alone through merely adding extra ones for the additional power.

When this situation has arisen in the past, the only solution has been to change the characteristics of the conveyor by changing the belt to a type with a high tensile strength and to install a new conveyor drive of sufficient horsepower to meet the new conditions. This traditional solution involves major capitcl expenditure in conveyor belt and drives, together with excavations to accommodate the larger head drive unit.

3.2. Effects on Conveyor Design.

The benefits of linear drives have the following effects on conveyor design.

(i) The use of small purpose designed drive units eliminates extra mining operations for their installation.

(ii) Ease of shipment inbye when access to a new district is restricted by old or small roadways.

(iii) It enables the use of low strength, low weight, conveyor belting, with reduced capital and replacemnnt cost.

(iv) Individual conveyors can be made longer at minimum extra cost and inconvenience.

(v) Standardisation of the grade and type of conveyor belting used in the mine regardless of the total installed driving power.

(vi) Belt speeds can be kept relatively low, so enabling longer distance top and bottom belt manriding, without the time consuming mounting and dismounting activity, thus decreasing overall journey time.

In addition to these practical "Pitmatic" advantages many application studies have predicted an overall capital cost saving with linear drive systems compared to the conventionally powered belt system. This varies with the details of the situation, between 10 to 30% when mechanical, electrical and belting costs are summated.

Fig.13 An example of a linear drive belt conveyor, applied to a new installation, is that in Fig.13. The main drift conveyor is 1.7 Km long, rising 284 metres. Initially the system is to deal with 500 t/hr of Kalvanite rising eventually to 1000 t/hr. Narrow high speed belts were recommended with initially a power of 800 HP (600 kW) distributed between a 400 HP head drive and a 400 HP (300 kW) linear drive. Additional 200 HP (150 kW) power packs are added, together with a second linear drive, to attain a final installed power of 1400 HP (1050 kW), using a 800 mm wide Type 8 fabric belt. Reference to Fig.4 will show that this would have been impossible with a single Head Drive design.

4. CONCLUSION.

The development of high strength belts and linear drives has opened up the use of single flight high power conveyors with the following benefits :-

(i) The flexibility of the tensile carrying member of belting leads to a minimum size to power ratio, which minimises the size of the Drive House, take-up and loading point excavation and hence greatly reduces the total cost of the installation.

(ii) The flexibility of the belt allowed by its design allows tolerance of undulations in roadways and therefore simple installation work as well as tolerance of ground movement after installation.

(iii) The inclusion of the tensile member within the carcase of the belt, protects it from corrosion and cushions it when going around pulleys and over idlers and return rollers, thus prolonging its life.

(iv) Because the tension member is protected, friction type drives of the linear type can be used.

(v) This in turn leads to yet more compact conveyor systems because a high power system can be constructed using specifically designed, narrow width conveyor drives.

(vi) Additionally it lowers the stresses in the belt, giving cheaper more handleable belts, yet at the same time attains all the benefits of a single flight conveyor with no transfer points.

LOCATION	LENGTH (m)	LIFT (m)	POWER (kW)	H.P.	LOAD (T/hr)	SPEED (m/s)	WIDTH (mm)	BELT TYPE
British Steel	1981	86	448	600	900	1.68	1200	ST.2250
Dew Mill (Inbye)	960	239	900	1200	650	2.54	1050	ST.2700
Dew Mill (Outbye)	1300	315	900	1200	650	2.54	1050	ST.2700
Cadley Hill	1143	270	522	700	900	2.54	1050	ST.2250
Rawdon	864	158	448	600	650	2.58	1050	Fabric type 12
Blaenant	800	200	600	800	800	2.64	1050	Fabric type 12
Bogside	2526	160	448	600	550	2.13	915	Fabric type 12
Seafield (MX)	1185	176	500	700	700	2.13	1050	Fabric type 12
Seafield (1250 HP)	1122	269	933	1250	1000	3.80	1050	Fabric type 15
Treforgan	1646	257	600	800	400	2.65	1050	Fabric type 12
Turkey (Downhill)	1100	-130	448	600	1200	2.03	1000	ST.2250
Coventry	670	35	448	600	2300	2.80	1350	Fabric 10
Harworth	397	58	448	600	1600	2.54	1350	Fabric 10
Welbeck	1765	220	896	1200	800	2.66	1050	ST.3000
Dew Mill(20's Leg)	960	24	448	600	2300	2.8	1350	Fabric type 10
Dew Mill(Bunker)	455	90	448	600	1400	2.79	1200	Fabric type 10
Agecroft	838	176	600	800	750	2.1	1200	Fabric type 12
Selby	15000	1000	10100	13500	3200	8.4	1300	ST.7100
Woolley	736	72	750	1000	1300	3.0	1350	Fabric type 12
Thurcroft	935	149	670	900	1100	3.2	1200	Fabric type 10
Grimethorpe	1344	80	670	900	1300	3.3	1050	Fabric type 12

FIG 1.

FABRIC
SOLID WOVEN

Type	Min. Warp Strength lbs/inch	kg/cm	App. Min. Weight kg/m^2	Thickness mm	Driving Drum Diameter	Elongation at Break
6	6500	1160	14.75	12	630 mm)	
8	8000	1430	15.30	13.5	760 mm)	
10	10000	1790	18.58	14.5	800 mm)	15% to 30%
12	12000	2150	19.13	15.0	1000 mm)	
15	15000	2687	20.00	15.5	1250 mm)	
20	20000*	3582				

*Not yet available.

Belt covers top 2 mm nitrile
Standard Bottom cover PVC.

STEEL CORD
ST NUMBER x (App. Min. BK Strength kg/cm)

Type	Min. Warp Strength kg/cm	App. Min. Weight kg/m^2	App.Min. Thickness mm	Driving Drum Diameter	Elongation at Break
1150	1150	20.5	14	630 mm)	
1400	1400	22.5	15	800 mm)	
1600	1600	23.5	15.3	800 mm)	
2000	2000	24.5	15.6	800 mm)	2.0 to 3.0%
2500	2500	29.4	17	1000 mm)	
3500	3500	39.0	22	1400 mm)	
4000	4000	42.6	23	1400 mm)	

Belt covers: Minimum top and bottom 5 mm thick, in rubber compounded to suit belting standard for ST1150 to ST2500.

Belt covers: Minimum top and bottom 7 mm thick in rubber compounded to suit belting standard for ST3500 and ST4000.

FIGURE 2

DTP1

GRAPH OF APPROX BELT COST AGAINST WORKING TENSION/HP AT DRIVE DRUMS. BASED ON 1000 mm WIDE BELT

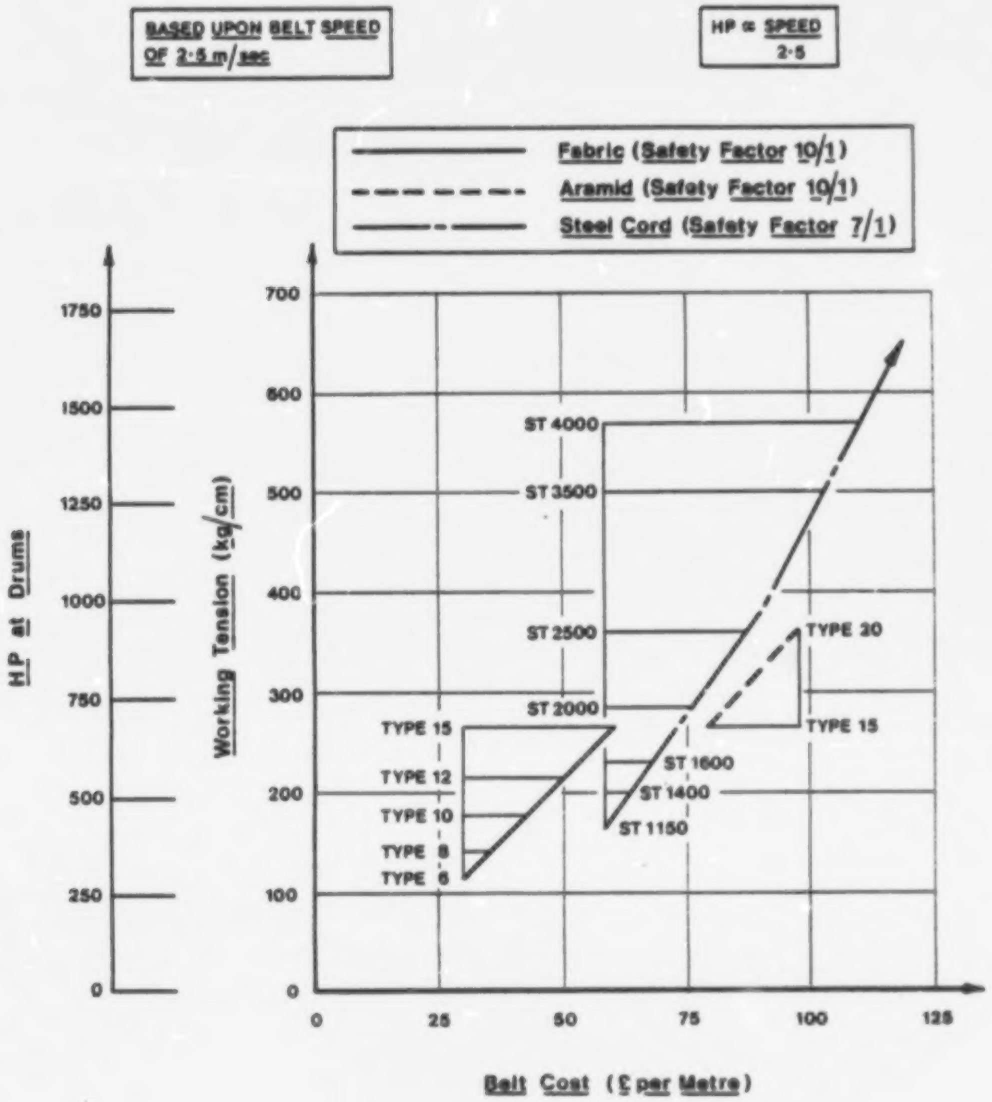
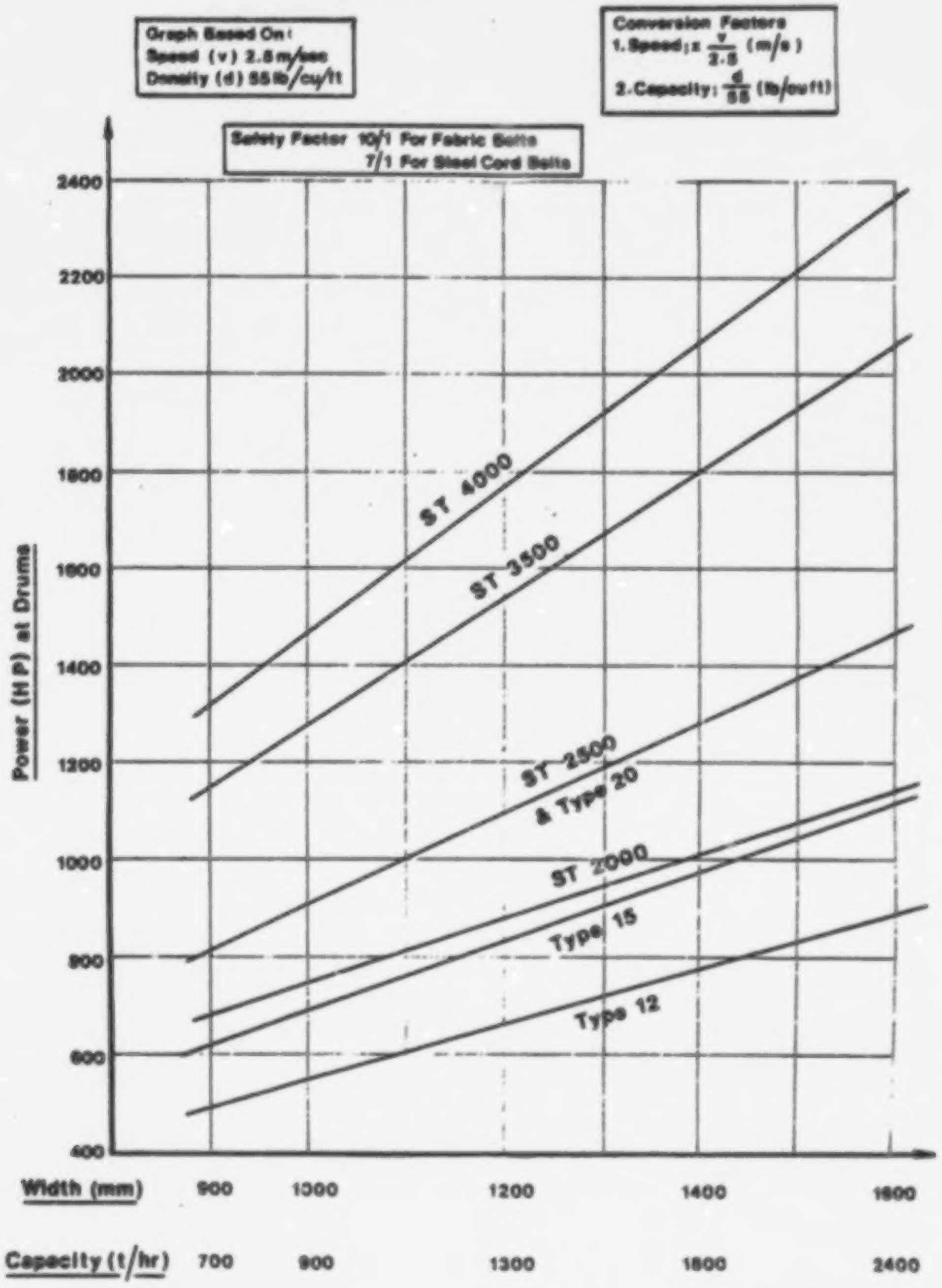


FIG 3.

GRAPH OF APPROX POWER AGAINST BELT WIDTH AND CAPACITY FOR FABRIC & STEEL CORD BELTS



Graph Based On:
Speed (v) 2.5 m/sec
Density (d) 55 lb/cu/ft

Conversion Factors
1. Speed; x $\frac{v}{2.5}$ (m/s)
2. Capacity: $\frac{d}{55}$ (lb/cu ft)

Safety Factor 10/1 For Fabric Belts
7/1 For Steel Cord Belts

FIG 4.

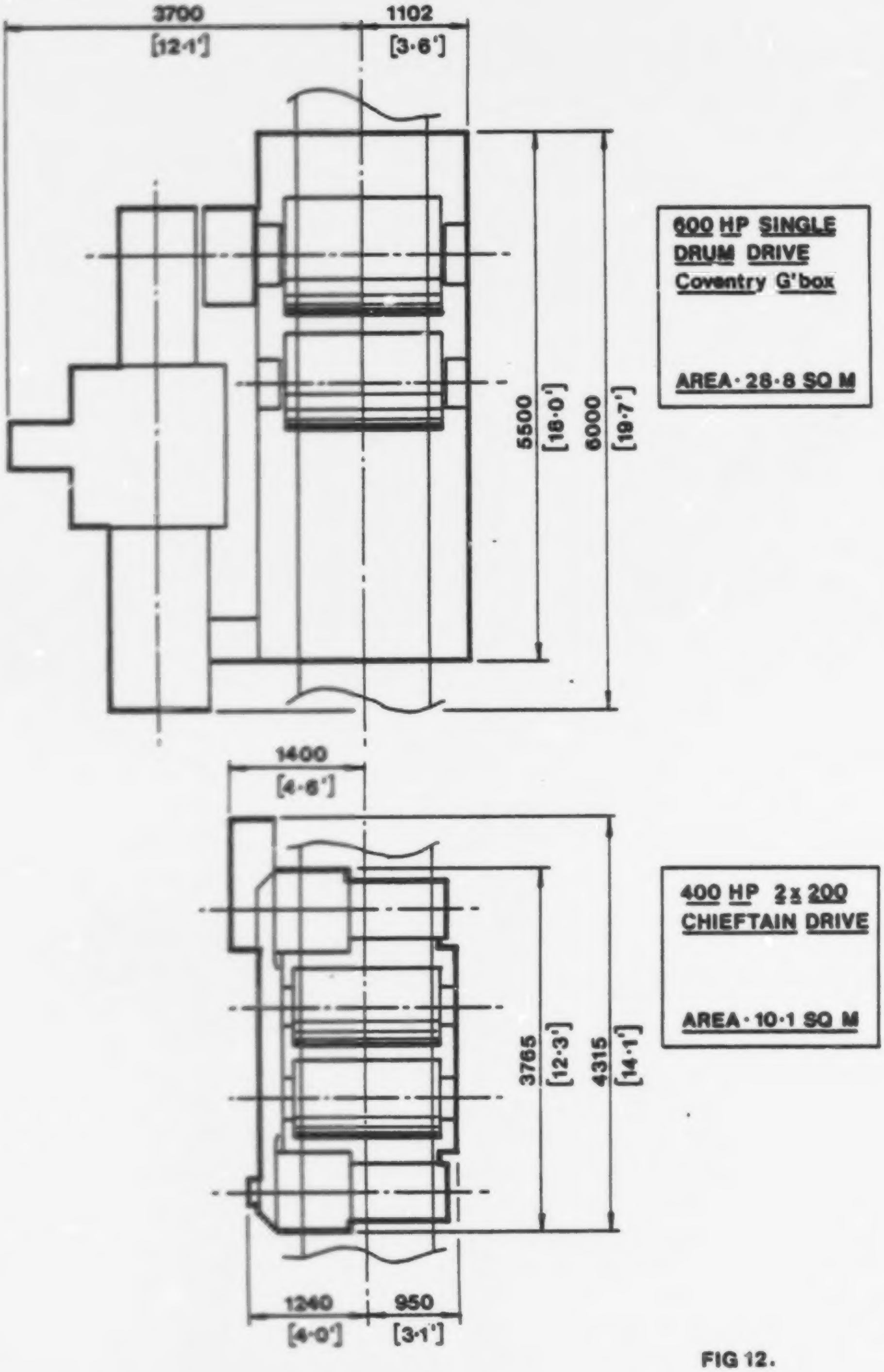

3700
[12·1']
1102
[3·6']
5500
[18·0']
6000
[19·7']
600 HP SINGLE
DRUM DRIVE
Coventry G'box
AREA · 28·8 SQ M
1400
[4·6']
3765
[12·3']
4315
[14·1']
400 HP 2 x 200
CHIEFTAIN DRIVE
AREA · 10·1 SQ M
1240
[4·0']
950
[3·1']

FIG 12.

ABMEC '83
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LONG DISTANCE BELT CONVEYING

T.B.G.Langley
Sales Manager
Cable Belt Limited

Belt conveyors have been used by the world's mining industries for well over a century. The object of this paper is to briefly emphasise the rapid developments in the field of conveying that have taken place during the past thirty years. The days are recalled when a conveyor of 300 HP was considered a major installation, whereas today, conveyors of more than 10,000 HP have been engineered and are being put to work. Also with the advent of bigger drives running at faster speeds and already propelling material further than 30 km (conveyor length, not belt length) without interruption, a look into the future indicates that as these large conveyors become more flexible, they will replace the more traditional forms of transportation in many instances.

LEGEND

The cable belt conveyor was designed and developed in the early 1950's by the Scottish Engineer and inventor, Mr. Charles Thomson, who foresaw the need to develop longer, single flight, belt conveyors, for the world's expanding mining industries.

At about the same time, the British National Coal Board (then only 3 years old) embarked on a programme of increasing coal production from existing and newly planned mines. This was partly achieved by a move away from vertical shafts to surface drifts, or declines. These were particularly suitable for the installation of conveyors, and the most obvious way at that time was to install a number of low horsepowered systems in tandem, but then, as now, this was found to be undesirable as it highlighted many disadvantages, amongst them, transfer spillage, sequence control problems and reduced overall system reliability. The need, therefore, arose for single drive conveyors to handle higher lifts over longer lengths, resulting in greater horsepower requirements.

After all, the standard belt conveyor in operation at that time had been used for around 100 years, without any significant changes in principle. The stage was therefore set to accept a new engineering concept to solve an age old problem.

In the early days of the cable belt conveyor development, most of the conveyors were purchased by the British National Coal Board. The first of these conveyors were for mines in Scotland, Northumberland and Yorkshire. It should be remembered that in the days of cotton duck conventional belting, before the widespread introduction of synthetic fibre and steel cord belts, these 300 to 400 horsepower conveyors were regarded as outstanding. They are now of course operating at much higher horsepowers and the standard drive unit range goes up to 6,000 kW, with special units capable of transmitting 10,000 kW.

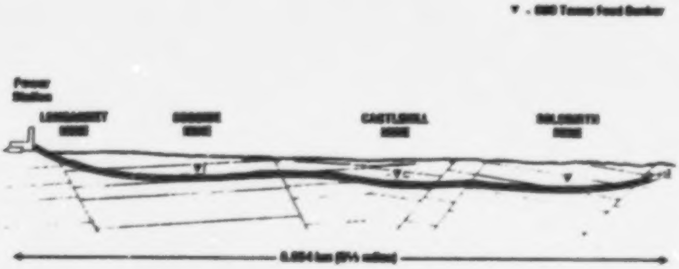
The basic principle of the cable belt conveyor is that the driving and carrying mediums are separated. Over the last 30 years many changes have been made to the initial design, but the original concept is still retained - a laterally rigid, but longitudinally flexible belt, supported at or near its edges on two parallel endless loops of drive cable. With this system the belt does not, as with the conventional belt conveyor, have to be pulled through continuous troughing idler sets to achieve the cross-sectional shape needed to accommodate the mineral load. The load configuration is achieved by a natural troughing of the belt, only when material is loaded onto it.

The concept of separating the driving and material carrying functions was recognised by engineers, and indeed conveyors such as bucket conveyors, which utilise the same design principle, still perform this function today. However, in belt conveying there was a need to find a strong, flexible medium to transmit the driving forces. Such a medium existed in steel cables and although many attempts were made to develop a system utilising this medium, the cable belt system was the only one to succeed. The reason for this was basically that the belt, i.e., the carrying medium, was not fixed to the driving cables, it simply sat on the cables being positively located with guides. Thus, in 1949, in Scotland the cable belt system was formed and the Company's history began.

Since those early days the cable belt system has developed in its range mainly in surface/underground decline applications, which called for higher and higher power transmission, and the ability of the cable belt conveyor to drive from a single position on the surface also offered considerable advantages for these applications.

Resultantly, a significant milestone was reached in the mid 1960's when the National Coal Board ordered a 2,000 HP x 9 km long cable belt conveyor for the Longannet complex (4 mines) in Scotland. This conveyor is still operating.

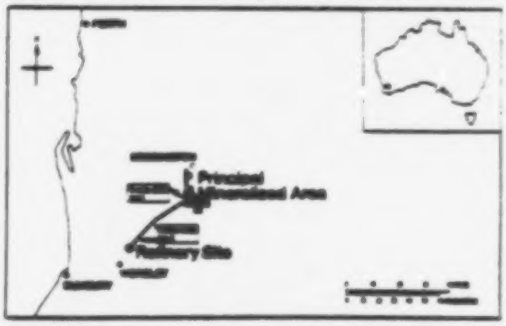
Figure 1.
Longannet Complex



However, it was not until the late 1960's that the significance of some of the design features of the cable belt conveyor began to be realised. Unlike the high lift applications, in which most of the power consumed is used to lift the material vertically, on horizontal applications the bulk of the power is consumed in overcoming frictional forces. It was only then that long overland conveyor applications started to become commercially attractive. These applications obviously offered great potential and by 1970 the longest single flight conveyor had been constructed in the USA. This 15 km long cable belt conveyor is still operating and carries coal at a rate of 1,500 tph.

During the 1970's there was a demand to carry larger quantities of bulk materials over even longer distances and with the increasing cost of the traditional labour intensive methods of transportation, conveyors became a more attractive alternative method of transportation for these overland applications. In fact, the majority of cable belt systems installed nowadays are overland applications and this has obviously represented a major change in conveyor technology. The most recent single drive installations being put to work in Australia are of lengths in excess of 21 km and 30 km.

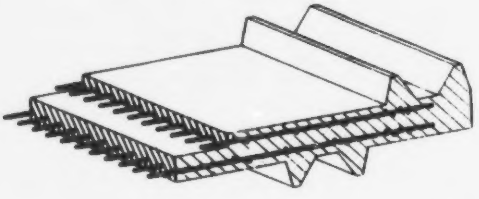
Figure 2
Route of 51 km installation



THE CABLE BELT SYSTEM

The cable belt conveyor comprises two endless steel wire driving cables one on either side of, and supporting, an endless loop of belt. The endless belt has continuous 'V' form grooves moulded along either side to suit the cable diameter and this belt is carried on the cables on both the carrying and return runs. Moulded within the belt is transverse stiffening which allows the belt to run flat when empty and trough naturally when loaded with material.

Figure 3
Belting



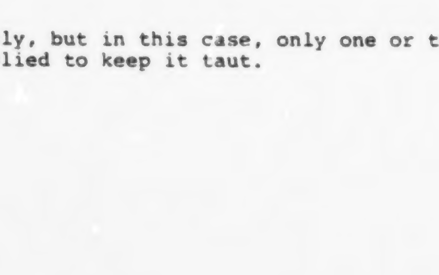
The amount of deflection varies between approximately 5% and 15% and is controlled to suit the density and lump size of the material to be carried. No continuous structure is required for the cable belt conveyor, instead line pulley stands are provided at suitable centres, depending on the capacity. Mounted on these linestands are line pulley assemblies arranged in twin configuration by virtue of rocker bars. The rocker bars are designed to pivot horizontally and vertically to ensure correct alignment with the drive cables.

The drive cables are driven by large diameter friction wheels mounted on either side of the driving unit. Incorporated within this driving unit is a differential gear to ensure that each driving wheel maintains the same peripheral speed and at the same time synchronising the power transmitted by each drive cable.

At either end of the conveyor, the belt is transferred from one run of cable to the other by a simple deflecting unit which enables the belt to pass between the cables.

The driving cables are tensioned independently to cater for any variation in stretch.

Figure 4
Cable tensioning arrangement

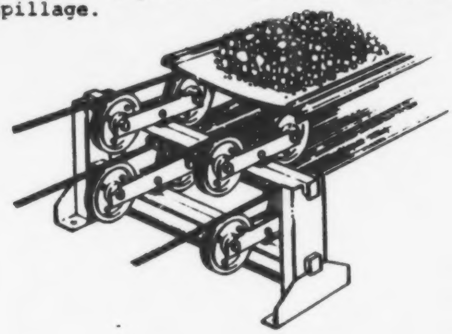


The belt is also tensioned independently, but in this case, only one or two kilograms per centimetre width is supplied to keep it taut.

The conveyor driving unit and the cable tensioning arrangement can virtually be positioned at any point along the system to suit the particular site conditions.

Drive between belt and cable is achieved through frictional contact assisted by the wedging action of the continuous 'V' shoe form sections, moulded as an integral part of the belt. The combination of cable and belt provides some significant differences to that of troughed belt conveyors. The cables are supported on pulleys, never allowing the belt to come in contact with moving or supporting idlers throughout the length of the conveyor. The belt is not therefore pulled over troughing idlers and this, of course, reduces the consumed power. The overall system therefore, has a much lower resistance to motion and offers considerable cost savings over long distances, compared with other systems. The supporting pulleys positively locate the cable and thus the belt, provides positive tracking, which has the advantage of avoiding spillage.

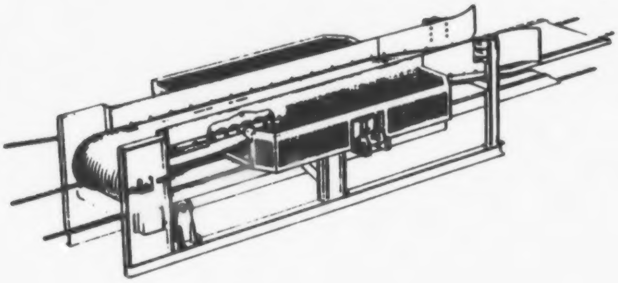
Figure 5
Typical 8 pulley Linestand



A further point about the motion of the cable belt system is that the material being conveyed has no significant movement on the belt during transit. The material is therefore allowed to retain its natural surcharge angle and consequently gives the maximum capacity for comparable belt width.

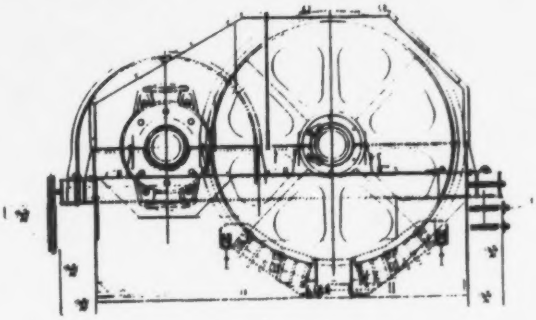
The terminal arrangements for the cable belt conveyor tend to be somewhat more complicated than for troughed belt conveying, as it is necessary to provide a method of entry and exit for the cables to locate with the belt. The belt is returned around the head or tail pulley, the size of which remains the same regardless of the size of the conveyor. The driving cables are extracted from location with the belt by means of deflection pulleys.

Figure 6
Head Discharge Unit



The cables are then routed to the driving sheaves which are driven through a common gear box which incorporates the tension equalising differential unit. The cables are then returned to the underside of the return run of belt through a further series of deflection pulleys. The head pulley can be located forward or behind the main cable driving sheaves. The relatively large driving sheaves result in much slower rotational speed than would be normal for conventional conveyors. This gives rise to a large ratio gear set and hence a large driving unit compared with similarly rated hp gearboxes for troughed belt conveyors.

Figure 7
12,000 HP Drive Unit



At the point of loading, the belt is also supported by impact idlers set at a pre-determined trough no greater than that set for the required carrying capacity. Skirt plates are located above the belt to contain the material within the width of the belting during loading. Centralisation of load is not necessary to ensure good tracking of cable belt belting.

PLAN DEVIATIONS

A very important feature of modern long distance conveying is the ability to curve the line of conveyor in order to avoid natural or man-made obstacles en route, thus eliminating the nuisance value of extra drives and associated expense.

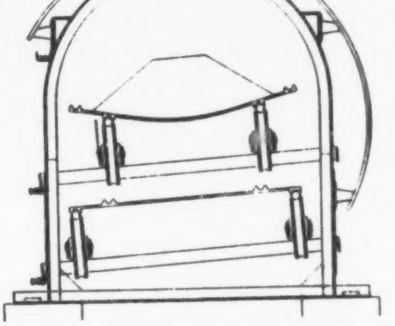
With the cable belt system this can be accomplished in two ways :

(i) Natural Curves

The first of these was installed in 1955 at NCB's Thornhill Colliery and since then eight similar installations have been made, handling a variety of materials over ever increasing distances.

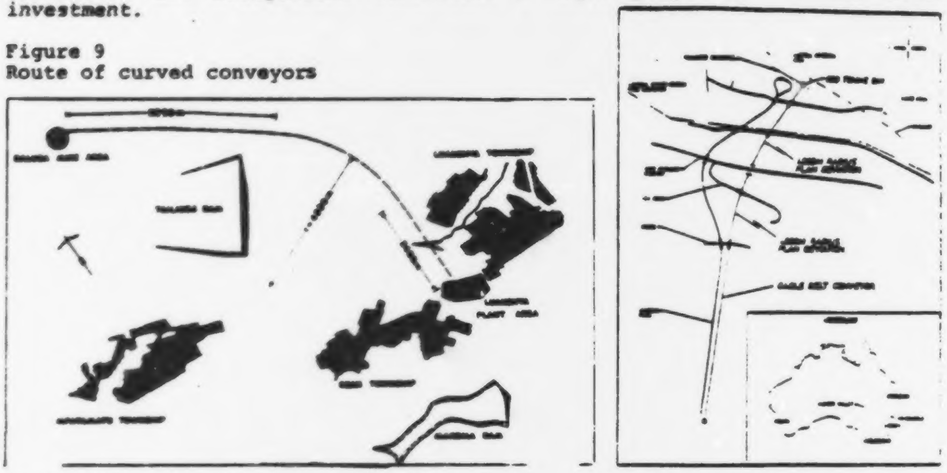
The principle of curving a cable belt conveyor is to incline the belt supporting linestands outwards from the centre of curvature, i.e. similar to a railway curve, but in the opposite direction. The radius of the curve being dependent on the drive tensions in the system at that particular point.

Figure 8
Inclined linestand



For example, two curved cable belt conveyor are illustrated in figure 9, but the most significant project yet achieved is a more recent overland conveying contract in India, where there will be a multiplicity of major horizontal curves combined with vertical curves over a distance of almost 15 km. This is the sixth single flight conveyor system over 14 kms in length to be constructed using the cable belt system. Computer aided design plays a very important part in ensuring the best and most economical line when confronted with difficult routing and rough terrain problems, as earthworks and bridgeworks constitute a major proportion of the total investment.

Figure 9
Route of curved conveyors



In addition to the two cable belt systems with large horizontal curves illustrated above, details of two of the most impressive installations to date are shown below:

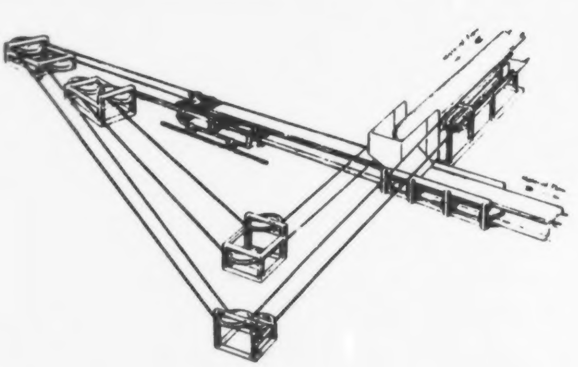
Client	Location	Length	Capacity	Power	No.of Curves	Supplier
Le Nickel (Mea Mine)	New Caledonia	11.12 km	600tph	1,100kW	4	C.G.E/ Tecminemet/ REI
NALCO (Orissa)	India	14.6 km	1,800tph	2,000kW	10	Cable Belt

(ii) Angle Transfer Station

When it is impossible, due to space restrictions, to curve a conveyor naturally the cable belt system has the ability to make sharp, drastic plan deviations by employing a unique device called the angle transfer station. The popularity of this special unit is increasing as the number of long distance projects increase. The maximum number of these units used to date in any one system is three, i.e. four conveyor legs, having only one drive source.

During the past five years two such installations have achieved throughputs of 5 mtpy and 7.5 mtpy at conveying rates of up to 2,500 tph.

Figure 10
Angle Transfer Station layout



LIMITATIONS OF OPERATION

The limitation of any conveyor (or system) usually depends upon the length and lift involved, the capacity to be handled and its competitive relationship with other modes of transportation. It is therefore, generally accepted in the modern world, with ever increasing labour and fuel costs, that within the range of 5 kms to 100 kms conveyors will provide the most economical solution if the capacity requirements exceed 500 tph or 2 mtpy. To prove this point, of the many detailed project studies that have been carried out during the past 15 years or so, the two most outstanding instances where conveyor systems were selected are listed below :

Client	Location	Length	Capacity	Power kW	No.of flights	Supplier
Enminsa	Bu-Craa, Sahara	100 km	2,000 tph	19,000	11	Krupp
Worsley	W. Australia	51 km	2,050 tph	8,500	2	Cable Belt

From feasibility exercises currently being undertaken, it is confidently believed that conveyor systems in excess of 100 km in length will be in operation before the end of this century, handling annual throughputs in the 10 M ton plus range.

Finally, before closing this section and for those of us more connected with the British Coal Mining scene you will no doubt have read about the futuristic plans for Selby mine in the NCB's North Yorkshire area. This mine complex is being developed to produce 50,000 tons of coal per day and Cable Belt Ltd. has been commissioned to design, supply and install a single drive conveyor in the North Drift spine roadway.

Anderson Strathclyde PLC, Glasgow are responsible for the conveyor being installed in the South Drift.

These systems should be fully operational before 1990 and although both are capable of handling the entire output of all 5 satellite mines of the complex, each conveyor will in effect, transport 5 mtpy of coal to the surface at Gascoigne Wood marshalling site, details as follows:

Client	Location	Length	Lift	Capacity	Power	Belt Width	Supplier
NCB	N.Drift	15 km	990m	1,830tph	8,750kW	1050mm	Cable Belt
NCB	S.Drift	15 km	990m	1,830tph	10,100kW	1300mm	Anderson Strathclyde

In summary therefore, and in the light of expertise gained during more than 30 years specialised experience, we are satisfied that with additional improvements already past the "drawing board" stage, conveyors of even longer lengths and possibly greater horsepowers will be made available to the world's mining industries, within the foreseeable future.

I trust this brief description of long distance belt conveying and in particular the accelerated development of the cable belt system during recent years, will excite your imagination and give food for thought when you next sit down to examine all the available options for transporting large quantities of minerals over long distances, efficiently, reliably and economically.

Acknowledgements:

National Coal Board, UK
Worsley Alumina (Pty) Ltd., Australia
Coal & Allied (Pty) Ltd., Australia
National Aluminium Co. Ltd., India
Le Nickel, New Caledonia.

Huwood

HIGH HORSE POWER BELT CONVEYORS

A MINING VIEWPOINT

by

Tom Fenton CEng. FIMinE.

HIGH H.P. BELT CONVEYORS

A MINING VIEWPOINT

by

Tom Fenton, CEng FIMinE

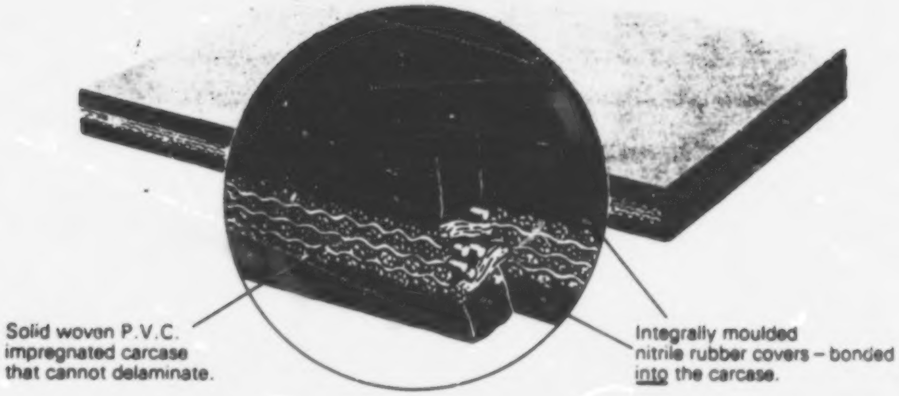
GENERAL INTRODUCTION

It is now possible to transport minerals by conveyor belt from the deepest workable measures by an incline drift to the surface. As productivity and the consequent output has increased, so has the power and tensile requirement of the conveyor drives and belt been developed to give the most efficient means of transporting mineral from the coal face to the surface.

This paper will examine solid woven fabric belts and steel cord belts which are available for high H.P. belt conveyors and will analyse the performance of heavy duty underground belt conveyors. Detailed case histories will be given of three of the conveyors mentioned. The cost of ownership, or more specifically, the cost per ton of mineral being conveyed, can often be inversely proportional to the initial purchased cost of the equipment. The correctly designed life specification and quality control manufacture of components, is essential to give long-life, trouble-free, reliable operation. Design and manufacturing aspects relating to reliability will be discussed.

THE CONVEYOR BELT

The belt is often the most expensive and invariably the most vulnerable part of the conveyor and too much care cannot be taken in selecting and looking after it. The factors which determine the selection of the conveyor belt are tensile strength, belt width, belt speed, joint efficiency and legislation relating to the safety of belts underground.


Solid woven P.V.C. impregnated carcase that cannot delaminate.
Integrally moulded nitrile rubber covers – bonded into the carcase.

SOLID WOVEN PVC BELT

The majority of belting supplied to the United Kingdom Mining Industry for use underground is of the solid woven p.v.c. impregnated type, this accounts for approximately 90% of the total requirement. Solid woven belting first became identified as a suitable design for conveying in the early 1950's. This followed a disastrous underground fire at Cresswell Colliery, where many fatalities were caused by the fire spreading from a belt conveyor.

In addition to the fire-resistant qualities of the belt, there are other advantageous attributes that are inherent in its construction, which are:-

Improved operating characteristics.	The belting being of homogenous nature tends to show superior troughing and tracking characteristics.
Delamination.	Ply belting delaminates in service through several reasons which are:- (a) impact (b) flexing round today's small pulleys, both breaking down the internal bond between plies and also covers and plies (c) edge wear, which then allows the ingress of moisture, dust, bacteria, etc. to attack the carcase fibres, destroying the belt.

Added Resistance to Edge-Wear	A constant problem, particularly where maintenance is restricted or limited. Today's solid woven belting has additional wear-resistance fibres to combat edge-wear.
	The substantial nature of the solid woven carcase provides additional load suport and a high resistance to impact at loading point.
Improved Fastener Holding.	The interwoven carcase design provides greater opportunity for fastener holding and resistance to pulling out or 'combing'.
Resistance to Longitudinal Tearing.	Again, the interwoven nature of the carcase is highly resistant to longitudinal tearing, and damage caused generally remaining localized.
Improved Flexibility.	This particular advantage of solid-woven belts, especially where high-tensile beltings are considered, has allowed the use of smaller pulleys.

All these improved characteristics manifest themselves not only in longer belt life, but also in the reduction of down time for joint repairs, belt replacement and renewal and installation time.

It has been possible, with the co-operation of the major manufacturers of solid woven belt conveyors, to analyse most underground belt conveyors in the United Kingdom using Type 10 and Type 12 conveyor belts.

The following charts give the specification and some operating history of these conveyors.

Heavy Duty Belt Conveyor Installations in the U.K.

Table 1

Colliery	Bentinck	Bagworth/ Nailstone	Silverdale	Silverdale	Killoch	Nostell
Conveyor Name	Surface Drift	Surface Drift	Surface Drift	No. 1 Drift	North Mine Drift	Surface Drift
Customer	N.C.B.	N.C.B.	N.C.B.	N.C.B.	N.C.B.	N.C.B.
Type of Belt	T.12s	T.10s	T.12s	T.10s	T.12s	T.12s
Belt Width (in.)	42	42	42	42	42	42
Belt Centres (ft.)	1800	2100	3000	1350	2000	2250
H.P.	600 DD	600 DD	800 DD	400 DD	700 DD	600 DD
Speed (F.P.M.)	500	512	500	500	500	450
Lift or Fall (ft.)	450	520	750	338	645	530
Load (tph)	800	600	750	750	700	600
Trough Angle	20°	27°	30°	30°	20°	22.1/2°
Drive Manufacturers	Huwood	Huwood	Huwood	Huwood	Huwood	FSW
Installation Date	Aug. 1970	July 1972	March 1975	Feb. 1982	July 1980	Aug. 1980
Tonnage to date (tons)	22×10^6	14×10^6	9×10^6	0.5×10^6	5×10^6	1.75×10^6

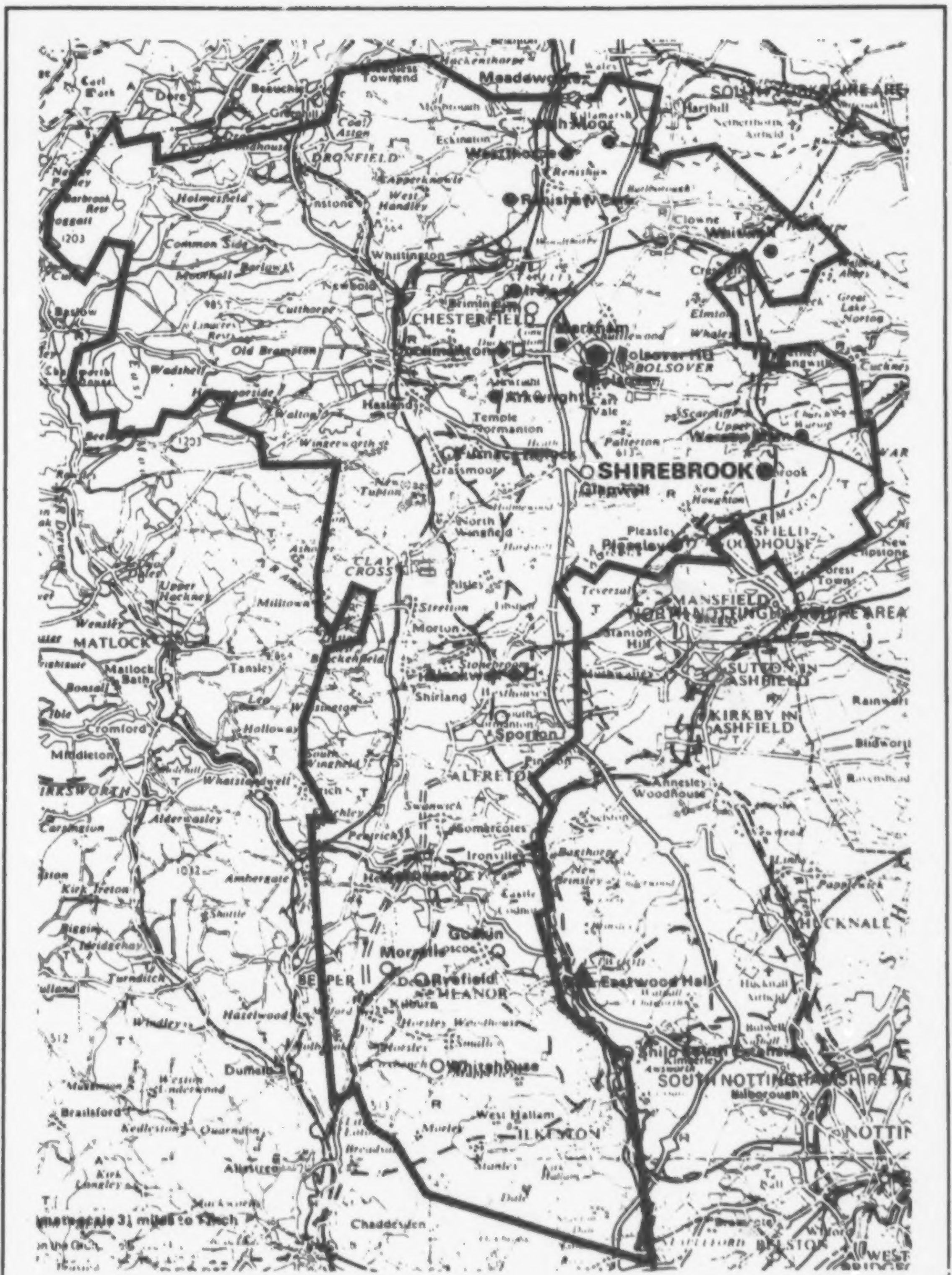
Table 2

Colliery	Blaenant	Bevercotes	Lynemouth	Shirebrook	Shirebrook	Shirebrook
Conveyor Name	Surface Drift		Bewick Drift	No. 1 Jubilee	No. 2 Drift	No. 3 Drift
Customer	N.C.B	N.C.B.	N.C.B.	N.C.B.	N.C.B.	N.C.B.
Type of Belt	T.12s	T.12s	T.10s	T.12s	T.12s	T.12s
Belt Width (in.)	42	42	48	48	42	48
Belt Centres (ft.)	2620	5620	2282	2920	2310	2350
H.P.	800 DD	600 DD	700 DD	900 DD + 450 Booster	900 DD	900 DD
Speed (F.P.M.)	512	550	500	620	620	620
Lift or Fall (ft.)	623	level	405	725	558	558
Load (tph)	800	900	1000	1000	800	800
Trough Angle	$22.1/2^{\circ}$	20°	30°	30°	30°	30°
Drive Manufacturers	Meco	FSW	Meco	Huwood	Huwood	Huwood
Installation date	Sept. 1976	Oct. 1976	Aug. 1977	Aug. 1978	Aug. 1978	Aug. 1978
Tonnage to date (tons)			16×10^6	10×10^6	10×10^6	6.25×10^6

Table 3

Colliery	Allerton Bywater	Rawdon	Rawdon	Treforgan	Holditch	Shirebrook
Conveyor Name	Surface Drift	Surface Drift		U/G Drift	South Crut	No. 2 Jubilee
Customer	N.C.B.	N:C.B.	N.C.B.	N.C.B.	N.C.B.	N.C.B.
Type of Belt	T.12s	T.12s	T.10s	T.12s	T.10s	T.12s
Belt Width (in.)	48	42	42	42	42	48
Belt Centres (ft.)	3444	2700	2296	4500	4198	1600
H.P.	900 DD	600 DD	450 DD	800 DD	450 DD	900 DD
Speed (F.P.M.)	590	500	490	512	395	500
Lift or Fall (ft)	771	520	434	933	750	361
Load (tph)	750	650	940	400	350	1000
Trough Angle	23°	30°	30°	30°	35°	30°
Drive Manufacturers	Huwood	Meco	Meco	Meco	Huwood	Huwood
Installation date	Dec. 1978	April 1979	April 1979	Aug. 1979	March 1980	Aug. 1980
Tonnage to date (tons)		3×10^6			1.25×10^6	

SHIREBROOK COLLIERY - NOTTINGHAMSHIRE, ENGLAND



The case history of Shirebrook Colliery is specifically described because this High Horse-Power Conveyor has been uprated by the use of a Booster Conveyor.

Shirebrook Colliery is located 17 miles north of Nottingham in the National Coal Board's North Derbyshire area and currently produces 1.6m tons per annum from it's seven longwall coal faces.

In the mid 1970's, production from the mine was 1.025m tons per annum, but further expansion was not possible due to the limit imposed by skip winding in the shaft. At this time, a coal blowing system was introduced into the winding shaft, which added an extra 200 tons per hour to the skip capacity of 400 tons per hour.

This, however, would still not meet the planned production of 1.6m tons per annum by the 1980's, so it was decided to drive a surface drift and convey all the coal out of the mine.

The drift, to be called a Jubilee Drift, since it began to convey coal in H.M. the Queen's Jubilee year, 1978, was begun in late 1976. It is a "Dog Leg" drift, the first part of which was driven at 1 in 4 for 960m at which point another inclined drift was driven 90° down 1 in 4 for a distance of 580m. A strata bunker was constructed in the original pit bottom and vibrating feeders served to regulate the peaks and troughs of coal flow and meter a fixed tonnage onto the drift conveyor system. The Jubilee drift conveyor is a Huwood 900 H.P. single flight conveyor, comprising two single-drum drive units, each powered by a 450 H.P. electric motor. The conveyor belt is 48" wide, Type 12 solid woven belt and runs on 5" dia. 30° troughed idler sets and 5" dia. flat return rollers.

At 900 H.P. the conveyor was rated at 750 tons per hour. In the second part of the drift, a Huwood 450 H.P. single drum drive was installed, using Type 10 belt 42" wide and again was rated at 750 tons per hour. Installation work on the above driveages was completed in August, 1978 and at the same time, two further 900 H.P. drives were completed to bring coal from the low seams. For the next two years, the conveyor carried coal at 750 tons per hour, 20 hours a day, without any loss due to mechanical breakdowns.

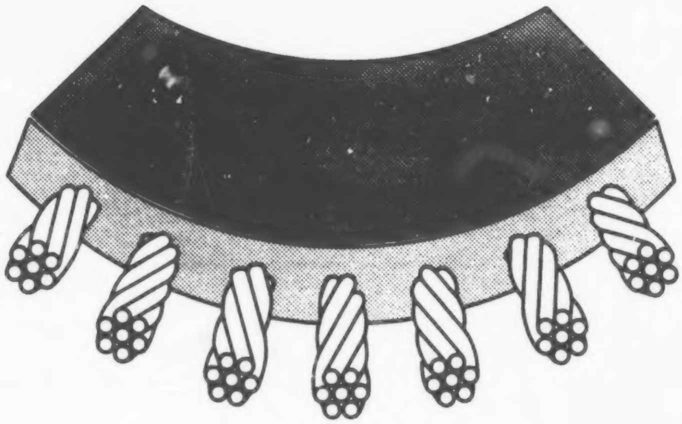
At nearby Pleasley Colliery, good reserves of coal still remain, but due to a limited shaft capacity and outdated steam winders, consideration was given to closure.

Following discussions with Huwood regarding the Jubilee and Intermediate Drift, it was decided to convey all Pleasley production underground to Shirebrook (approximately half a million tons from two faces). At a point some 600m down the Jubilee surface drift, a HUWOOD 450 H.P. Booster drive was installed, the drive being identical to all the other units in the system for standardisation purposes.

Type 12 42" wide conveyor belt is used for the booster drive, which is 6" narrower than the main belt. The above uprating took place in August, 1981 and coal from Pleasley Colliery has been conveyed up the system with Shirebrook coal since January 1982. The conveyors are now handling 1,000 tons per hour for 21 hours per day.

The total installed H.P. in the Jubilee drift is 1,350 H.P. (i.e. 900 head drive and 450 H.P. booster) making it the most powerful booster conveyor in the United Kingdom.

Again, this unit has run faultlessly for the past two years and has conveyed approximately 3 million tons in that time.



STEEL CORD BELTING

There are a number of attributes of steel cord construction which offer advantages in certain circumstances over the established solid woven construction. These are:-

High Strength.	Steel cord belts can be manufactured with breaking strength up to 7100 Kg per centimeter (40,000 lbs per in. width). This enables steeper and longer hauls and reduces transfer points.
Splicing Efficiency.	It is possible to make joints which have a life equal to that of the belt and with higher static and dynamic strengths than with any other construction. This enables factors of safety to be reduced from the accepted 8:1 used with solid woven belts, to as low as 5:1 with steel cord belt.
Flexibility.	The reinforcing cord lying in one plane give excellent transfers and longitudinal flexibility, enabling a 45° troughing angle to be used, as compared with a maximum recommended troughing angle of 30° for type 12 and type 15 solid woven belt.

The following chart compares the strongest currently available textile solid woven belt with the strongest steel cord belt:-

48" (1200mm) Belt	Type	Tensile Strength	Joint Efficiency	Safety Factor	Max. Drive H.P.	Max Carrying Capacity
Textile Solid Woven	15	15,000 lb inch width	70%	8:1	2800 H.P.	2600Ts hour
Steel Cord	FR7000	40,000 lb inch width	90%	5:1	12000 H.P.	2600Ts hours

Assumptions

1. 30° Troughing Angle - 3 Equal Roller Idler Set - 10° Surcharge Angle
2. T2 = 0.3T1
3. Belt Speed
4. Level Conveyor
5. Material Density 55 lb/ft^2
6. Drive Efficiency = 90% (Efficiency Built in)

It can be seen from the chart that over four times the H.P. can be transmitted through a steel cord belt. This comparison is a little unfair because the fabric belts currently available are approved for underground use, whereas steel cord belts do not yet have full approval.

There are two tests to which all conveyor belts must comply before they can be used underground. These are:-

(a) The flame test which ensures that a belt be completely non-flameproof, or self-extinguishing when a flame is removed from it.

(b) The drum friction test ensures that a belt be completely non-ignitible when held stationary against a rotating steel drum and also restricts the drum surface temperature to 300° centigrade.

It is also required that the test be continued until the test piece is worn through and breaks. It is not possible to design a steel cord belt to meet this requirement, but exemptions can sometimes be obtained when the conveyor drive is to be used on the surface of the mine.

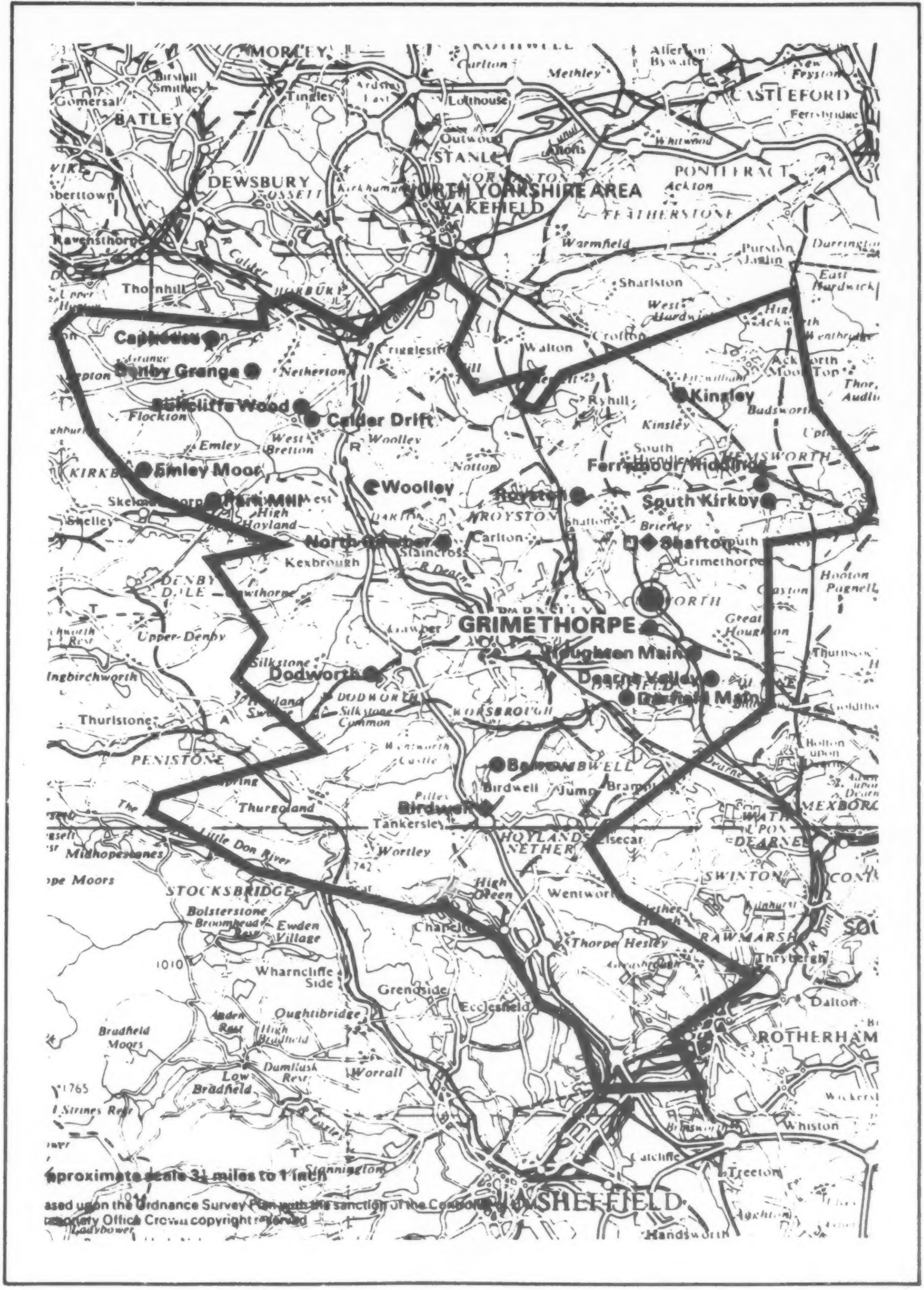
The following chart shows the "international requirement":-

Country	Spec. No.	Flame Test	Drum Friction	Propane Burner	Lab Tunnel	Large Gallery	Filter Test
International	ISO	x					
340 Europe							
U.K.	BS3289/1982	x	x	x			
U.K. (N.C.B.)	158/1980	x	x	x			
U.K. (B.S.C.)	As Canada	x	x				
E.E.C.	709 374		x	x			
Belgium	AS 709/74		x	x			
Germany	2 ply 1200mm		x	x	x(3)		x
	Other textile belts		x	x	x(3)	x(4)	x
France	NF T47 108 (1963)	x					
	also 709/74		x	x			
Poland	PN76-G 04030	x	x			x	
Rumania	STAS 8893-71	x					
Czechoslovakia	CSN 260370	x	x				
AMERICA							
U.S.A.	MSHA 30-CFR 18-65	x					
Canada	EMR 1C 215 FRL 269	x	x				
ASIA							
India	IS 3181 (1966)	x	x				
Japan	JIS K6324 (1966)	x					
AUSTRALASIA							
Australia	AS 1334 (1982)	x	x				
AFRICA							
South Africa	SABS 971 (1980)	x	x				

(3) Din 22118

(4) carried out at Tremonia

GRIMETHORPE COLLIERY - YORKSHIRE, ENGLAND



The Barnsley Area of the National Coal Board is spending a massive £400m to create a new coal field from old. The investment will complete a revolutionary programme to concentrate almost all the 150 year old area output currently running at 8.4m tons a year from seventeen Collieries, at three major coal handling points.

Most of the mines in each of the three complexes will be linked underground by a network of new roads. The major project will increase overall productivity by nearly one ton to 3.48 tons per man shift, compared to the present U.K. national average of 2.44 tons per man shift.

This project will be completed in 1985, when nearly 9 million tons of coal per year will be conveyed up three giant drifts, surfacing at Wooley, Grimethorpe and South Kirkby Collieries. At each of these three key nerve centres, coal belts will feed into new generation central washeries, capable of preparing coal for steel making, power stations or the expanding industrial market.

Grimethorpe Colliery, near Barnsley, was sunk in 1894. There are three shafts and coal is wound from fully mechanised coal faces, producing 1,225,000 tons of coal for the New Hill, Fenton and Park-gate seams. Work is now in progress on a project to concentrate the output from Grimethorpe, Barrow, Darfield and Houghton Collieries by connecting mines through underground conveyors to a surface drift and a central coal preparation and disposal plant on the Grimethorpe surface. This project is referred to as the 'Barnsley Area South Side Project'.

The conveyor being installed in the surface drift is unique, in that it consists of two conveyors, one running above the other. These two major surface drift conveyors, both of which will commence operation by the end of 1983, are of HUWOOD manufacture. The lower conveyor will run the full length of the surface drift which is some 2,754m long and is powered by three 1,250 kW motors, giving a total of 3,750 kW.

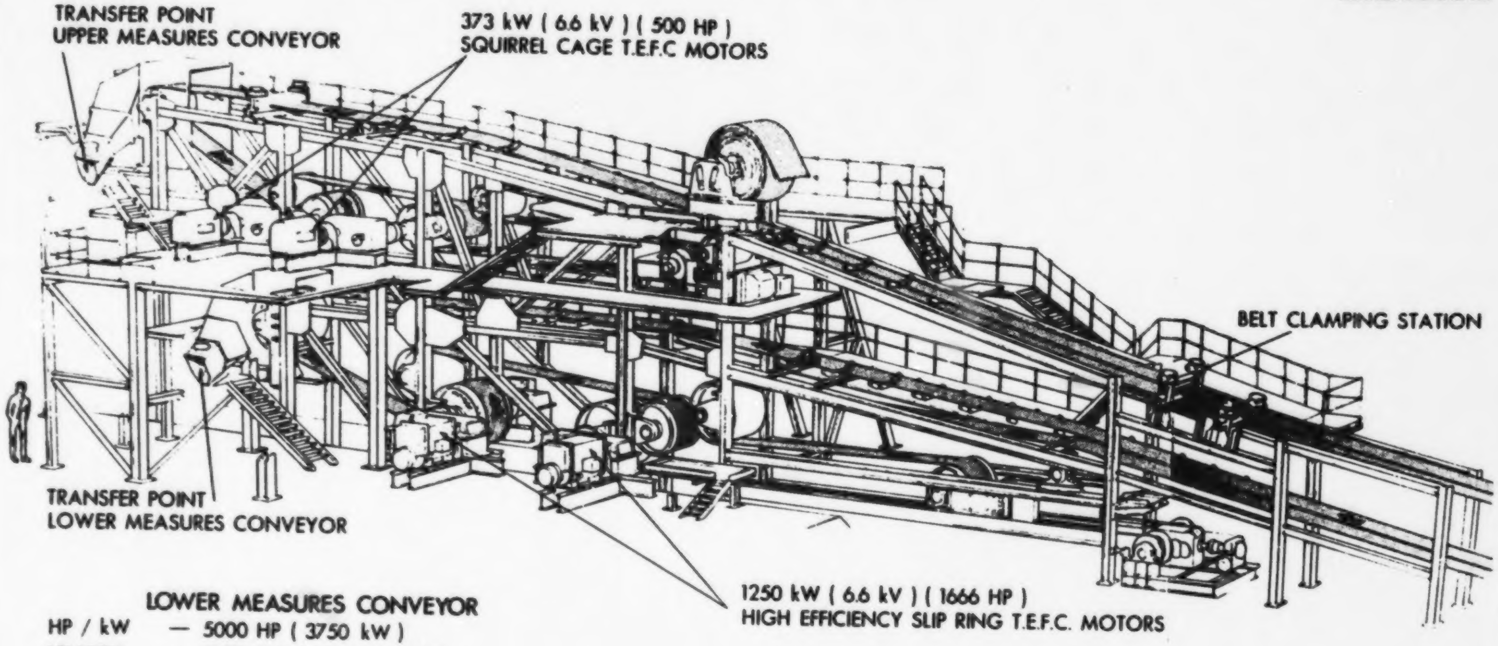
This conveyor is designed to run at 718 ft per minute and carry 1,300 tons per hour on 48" wide steel cord belting.

The steel cord belt has a tensile strength of 40,000 lbs per inch width and at the time of installation is the strongest belting ever made per unit width. The conveyor belt has a total weight of 500 tons which is made up of 16 rolls each 350m long and weighing 32 tons per roll.

Running over the top of this conveyor is another conveyor, designed to bring coal from the Newhill Seam which is necessary because of it's quality to keep separated from the lower measured coal.

This conveyor runs at 612 ft per minute and is designed to carry 550 tons per hour on a 48" wide belt over a length of 1300m. The drive is powered by two 500 H.P. non-flameproof motors.

N.C.B. GRIMETHORPE COLLIERY SOUTHSIDE DRIFT CONVEYORS


TRANSFER POINT
UPPER MEASURES CONVEYOR
373 kW (6.6 kV) (500 HP)
SQUIRREL CAGE T.E.F.C MOTORS
BELT CLAMPING STATION
TRANSFER POINT
LOWER MEASURES CONVEYOR
1250 kW (6.6 kV) (1666 HP)
HIGH EFFICIENCY SLIP RING T.E.F.C. MOTORS

LOWER MEASURES CONVEYOR

HP / kW — 5000 HP (3750 kW)
LENGTH — 3012 YDS (2754 METRES)
LIFT — 761 YDS (696 METRES)
CAPACITY — 1300 TONNES / HR
BELT SPEED — 718 FT / MIN (3.647 M / S)
BELT WIDTH — 48" (1200 mm)
BELT TYPE — FR 7000 STEEL CORD
(TENSILE STRENGTH 40,000 lb /INCH OR
7,000 kN–M / INCH WIDTH OF BELT)

AT THE TIME OF INSTALLATION THIS WAS THE WORLDS STRONGEST BELT / INCH WIDTH

UPPER MEASURES CONVEYOR

HP / kW — 1000 HP (746 kW)
LENGTH — 1420 YDS (1300 METRES)
LIFT — 360 YDS (331 METRES)
CAPACITY — 550 TONNES / HR
BELT SPEED — 612 FT / MIN (3.1 M / S)
BELT WIDTH — 48" (1200 mm)
BELT TYPE — 12 SOLID WOVEN

STOCKTON BOREHOLE COLLIERY - NEW SOUTH WALES, AUSTRALIA

This colliery is situated approximately thirteen miles South West of Newcastle, New South Wales, Australia, and is owned by the B.H.P. Company Limited.

Production is by continuous miners working the bord and pillar method.

The coal was originally brought to the surface by skip winding but because of its limitations and a decision to sink a new additional mine, (Macquarie Colliery) nearby, it was decided to drive a new surface drift and install a steel cord belt conveyor which would handle both collieries' productions.

A conveyor of the following specifications was selected:-

Length	1000 metres
Width	1050mm
Speed	2.7 metres per second
Gradient	1 in 3.18 against the load
Capacity	750 t.p.h.
Motor Horsepower	2 x 375 kW (2 x 500 H.P.) Slipring, 1450 r.p.m. 2200 volts
Drive Head	Huwood TB1000 comprising: dual drums, dual motors, equal load sharing
Troughing Angle	30°
Belting	This was 1050mm wide, Type ST3620, with 6.4mm thick neoprene covers

The conveyor was commissioned in 1973.

In 1981 it was decided to increase Stockton Borehole's and Macquarie's production to 1.4 and 2.18 million tons per annum respectively, by the use of longwall mining.

This necessitated the upgrading of the drift conveyor to 1000 tons per hour and 1120 kW (1500 H.P.).

As the present drive head could not be satisfactorily upgraded to convey 1000 tons per hour, consideration was given to:

(a) installing a booster conveyor,

and

(b) installing a new surface drive head.

Although a booster would have been more economical, because of the wet conditions of the drift and the major interruptions which would have been caused to the material transport down the drift, it was decided to opt for a new surface drive head to the following specification:-

Drive Head	Huwood TB1120 kW, comprising: dual drums, dual motors, equal load sharing with design capacity to convert with three motor drives, natural load sharing.
Motors	2 x 560 kW, (750 H.P.) squirrel cage. 1450 r.p.m., 3300 volts.
Fluid Couplings	Fluidrive size 66 GST, trim scoop couplings
Belt Speed	3.5 metres per second.

A Pony drive is fitted to the input shaft of the secondary gearbox and has a design capacity to run the conveyor (in winter) either forward of reverse without disconnecting the main motor, scoop couplings or primary gearbox.

This facility is required for belt installation, belt inspection, belt replacement etc.

The new drive head was installed without disrupting production and was commissioned during the collieries 1982/1983 Christmas/New Year annual holidays.

The original type ST3620 steel cord belt will be replaced in due course with a type SR4530 belt, 8 x 8mm neoprene covers.

The original TB1000 drive head which has conveyed over 7 millon tons of mineral is to be checked over and reinstalled in a different location.

PYRO MINING CO. - KENTUCKY U.S.A.

When considering the application of high horsepower conveyors, it is normally assumed that the system will include heavy duty drive equipment complete with either single or multiple power units. There are instances, however, where due to geological constraints or a desire to standardise on conveyor components or belting it is necessary to consider alternative forms of conveyor transmission.

These conditions did apply within an enquiry received from Pyro Mining Company in Kentucky U.S.A., when it stipulated that wherever possible, the equipment had to be accommodated within a 4'6" high roadway and the belting should conform to a 650lb per inch working tension standard. Two conveyor systems were required, each to the following specification:-

Conveyor Length - 20,000 feet
Vertical Lift - 600 feet
Duty - 1600 S.T.P.H.
Belt Width - [illegible]8"

It was estimated that the installed power for each conveyor would be 2500 H.P. and on this basis, a system was designed incorporating a 500 H.P. main drive and four intermediate booster conveyors. The booster conveyor system will be installed on an advancing basis, the 500 H.P. main drive operating initially and the booster conveyors being added progressively as the roadway advances.

Consideration had been given to a conventional system incorporating five conveyors operating in tandem, but the booster system was preferred due to the elimination of transfer points and the ability for the system to operate if a breakdown should occur on any of the individual power units.

In spite of considerable competition from U.S.A. and other conveyor equipment suppliers, Huwood Ltd. have been successful in securing the orders for both the Wheatcroft and Williamstation Mines.

Wheatcroft conveyor is scheduled for installation in November, 1983 and Williamstation for July, 1984.

THE COMPUTER

The conveyor drive units for very high Horse Power conveyors are individually designed to suit the particular application, and all rotating elements of these transmissions must be designed to give long-life, reliable, and safe operation.

Computer programmes have been developed which enable our Designers to specify quickly and accurately all components to be manufactured. A print-out summary of the design verification is sometimes requested as a check on the design parameters of the transmission.

To obtain these relatively simple print-outs, sophisticated design programmes have been developed which are based upon many years experience and standards laid down by internationally recognised bodies.

Computer Print-Out

```
HELICAL GEAR PAIR LOAD CAPACITY 20PA

TYPE IN VALUES FOR :- TP,TW,KP,KW,MODULE
? 17,70,.378,-.378,.28571
TP    TW    KP       KW          M
17    70 .3780    .3780-   .28571
IS DATA OK ? (Y OR N)
? Y
TYPE IN VALUES FOR :- HELIX,FACE,REVS,SBOP,SBOW
? 16.56,10.5,314,32400,32400
HELIX  FACE  REVS  SBOP   SBOW
16.55 10.500  314.0 32400  32400
IS DATA OK ? (Y OR N)
? Y
TYPE IN VALUES FOR :- LB,LC,HPNOM,KOP,KOW
? 10000,10000,400,1800,1800
 LB      LC     HPNOM   KOP   KOW
10000  10000    400.0  1800  1800
IS DATA OK ? (Y OR N)
? Y
```

INFORMATION IN:-

NO. OF TEETH ON GEARS.
DESIGN FACTOR.
PITCH.
GEAR TOOTH ANGLE.
WIDTH OF FACE.
SPEED OF GEARS.
ALLOWABLE BENDING STRESS.
LIFE OF GEARS (HOURS).
H.P. TO BE TRANSMITTED.
COMPRESSIVE STRENGTH.

```
MIN FACE WIDTH ALLOWABLE
 3.14921

       XP           XW          KP            KW         TVP           TVW
 .713849E-01   .782525E-02   .378           -.378              19.3038        79.4862
YTIPP   YTIPW
? .4362,.4171
 .4362          .4171

FOR A GIVEN LIFE  LB=10000  LC=10000 (HRS)
          HPB      HPC   SBALL       SCALL   KALL
PINION  473.6    540.7  18011        5003    1001
WHEEL   601.0    717.6  23903        6640    1328

FOR A GIVEN H.P. (NOM) OF  400.0
             (LIFE B)    (LIFE C)       (SB)
PINION         23303       45222        15213
 WHEEL         76708      186207        15910
```

INFORMATION OUT:-

H.P. THAT CAN BE TRANSMITTED
FOR 10,000 HOURS.
DESIGN LIFE OF GEARS.

QUALITY CONTROL

Formalised, quality control is a system whereby a customer can be assured that the equipment he has purchased is fit for its intended use. There is now a greater tendency for mine operators purchasing high horsepower belt conveyors to buy from suppliers who have proper quality systems. Quality assurance involves almost every aspect of a Company's business and a majority of it's employees.

Quality systems must be under constant review and update and be available for customer audit.

To give an example, there could be up to 50,000 belt conveyor rollers in a high H.P. conveyor system. Each of these rollers could potentially damage the very expensive conveyor belt, or worse, be the cause of an underground fire. It is therefore, essential that the quality of such items should be uniform and repeatable.

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   - Quality Records

LIFE FACTORS

When considering the reliability of any conveyor system, the lift ratings of the component parts must be established. Account must also be taken of tonnage to be transported, the number of operating hours per annum under the various load conditions, and the Operator's overall life requirement.

With a high tension installation, the following list will give a general guide to the lift expectancy of various components.

Conveyor Belt	This is usually the most expensive single item of equipment: it's life is largely determined by wear. For solid woven and ply belting, life expectancy of over 8 years is reasonable. For steel cord belts, a life of 15 to 20 years is possible.
Drive Gear Boxes	These should be designed to last the life of the conveyor, however replacement items such as bearings and seals should have a life span of 7 to 10 years.
Pulleys and Main Bearers	Generally speaking, these items require a shut-down period of 24 hours or more to replace and should have a life span of 7 to 10 year.
Conveyor Structure	This should last the life of the conveyor with easily replaceable carrying idlers, having a minimum life span of 5 to 10 years.

A number of components which have not been listed and for which life ratings are not normally given, such as chute linings, skirt plates and belt wipers, all of which are subject to heavy wear, require special attention to ensure ease of maintenance and replacement.

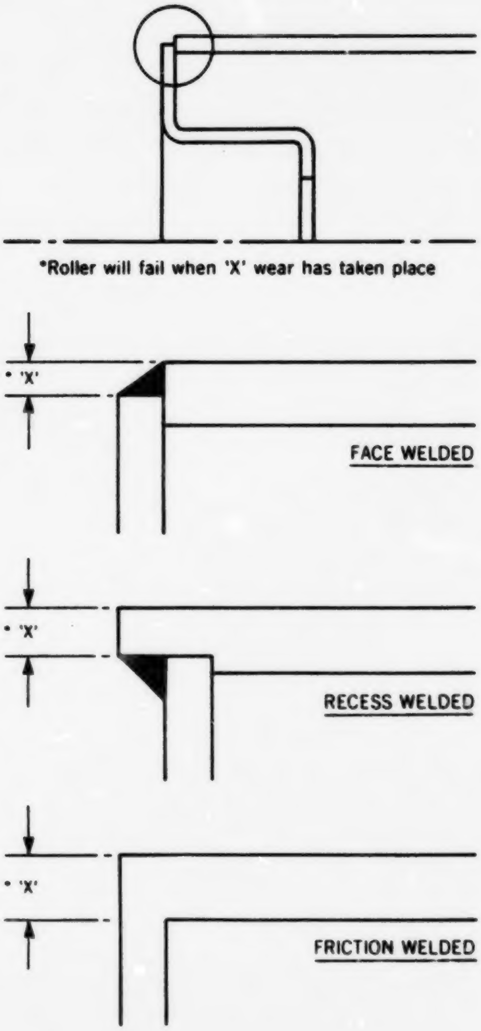
The planned life of a mine can vary from under ten years to more than a century. The overall life requirement of transport system is critical to the selection of equipment. The cost of ownership is a more important factor than the initial cost. Techniques of life cycle costing are being developed which in future will be a major factor in decisions made by mining engineers concerning the design and specification of transport systems.

MANUFACTURE

Expertise in the manufacture of conveyor components has been built up over many years. A good example of how improved manufacturing techniques affect conveyor reliability, is the development of friction welding for the manufacture of belt conveyor rollers.

The following illustration shows how the construction of conveyor roller bodies has improved. It has been previously mentioned that any failed conveyor roller in a conveyor system can damage the very expensive belt, or at worst, cause a fire. It is therefore of paramount importance that the mechanical construction of conveyor rollers give the best possible reliability.

CONVEYOR ROLLER BODY CONSTRUCTION



*Roller will fail when 'X' wear has taken place

CONCLUSION

The tremendously expanded capacity of modern high tension belting now makes conveyor drives of thousands of horsepower a reality and a considerable amount of design study has been carried out in recent years.

Safety legislation is an understandable constraint of the designers of high horsepower underground belt conveyors, particularly in development of high tensile fibres that will meet the requirements of the stalled drum test.

New temperature monitoring techniques for conveyor drive drums may, at some time in the near future, enable the stalled drum test to be replaced by monitoring. If this is possible, there will be a new era when much higher H.P. belt conveyors will be used underground.

In the meantime it is possible to engineer conveyors of almost unlimited length by booster conveyors. The roadway belt conveyor is likely to remain the most efficient and effective means of transporting minerals underground. It's use can be enhanced by control systems and automation but there is still a considerable amount of work yet to be done in this field.

Steel Cord Conveyor

*By C. T. MASSEY, BSc, CEng, FIMinE,
and J. DUNN, CEng, FIMechE, FIMEMME

C. T. Massey

J. Dunn

SYNOPSIS

The paper opens with a description of the Selby Coalfield with the five separate mines and the central coal clearance point at Gascoigne Wood.

The conveyor concept is discussed and the various options open to the designers in choosing a conveyor system which will meet the challenge of the present and to some extent the unknown factors likely to develop in the next century.

The requirements of the single drive conveyor are compared with other arrangements originally considered, also the requirements that the conveyor can handle the output from the five mines, via underground strata bunkers. The conveyor has to be flexible enough to cope with an extending coalfield and to work in an underground roadway which itself is being extended. The technical details of the conveyor are described, including the design of the surface drive unit with its single forged drive drum, twin DC variable speed motors, bearings and clutches. The take-up arrangements are described as well as the main drive house, foundations, gantries etc. The belt cleaning system, with washing and drying systems are described in detail, together with details of the idler sets and tail end unit. The belt installation and splicing operations are described as well as information on the control strategy and loading arrangements via accelerator conveyors.

The paper concludes with a factual report on problems encountered and describes how the conveyor is running successfully at a position 5200 m inbye and carrying up to 1000 t/h of material at just under half the maximum speed of 8·4 m/sec.

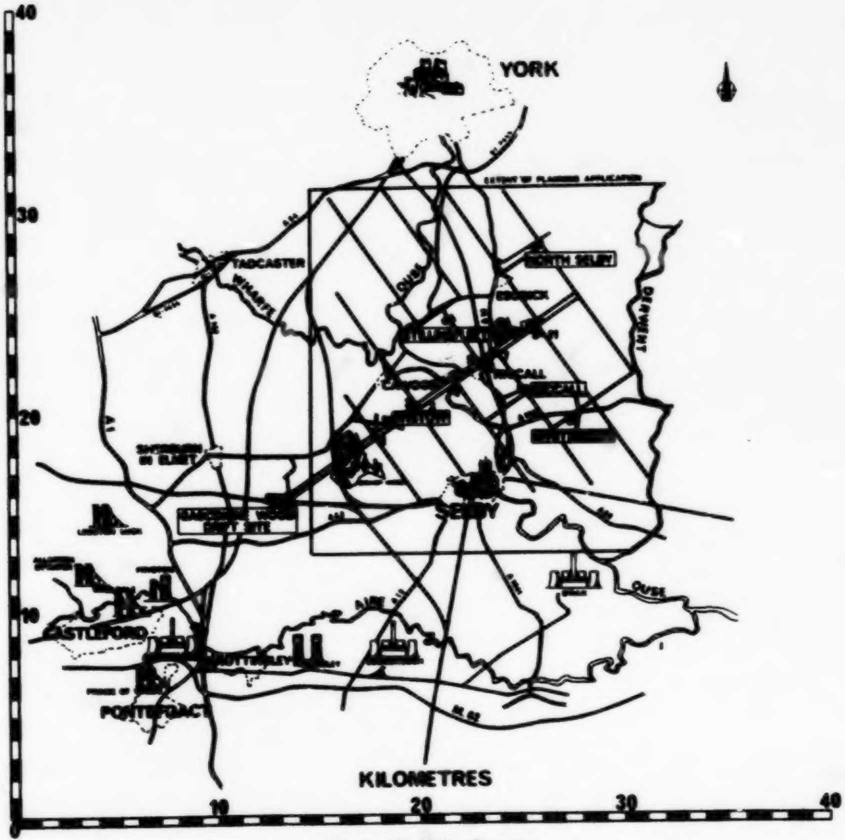


Fig. 1 The Selby Concept

1. INTRODUCTION

The starting point for the Selby Coalfield was the Coal Board exploration programme in the 1960s which established a potentially very large coalfield. Subsequent borings in the Vale of York indicated total reserves of 2000m tonnes and four or five workable seams, and 600m tonnes in the Barnsley Seam alone. The Barnsley Seam is 300 m deep along the western edge of the coalfield, and dips in a north-easterly direction until it is 1100 m deep on the north-east boundary of the coalfield.

The objective for the engineers designing the coalfield can be expressed simply as: 'To design a mining complex capable of producing 10m tonnes per year, taking the minimum acreage of land from agriculture, creating only 1 m of surface subsidence, transferring a suitable labour force into the coalfield area and organising the construction and development of the coalfield in such a way that it has minimum impact on the environment.' In no way could these parameters be satisfied by the construction of five self-contained mines, each capable of producing two million tonnes per year. Poor communications and lack of rail connections, apart from Gascoigne Wood, restricted consideration of the mines as separate coal producing units. The impact of such a solution on the agricultural life of the Vale of York would have been extensive.

**Mr Massey is Deputy Director (Mining), Selby Project, NCB North Yorkshire Area, and Mr Dunn is Area Chief Engineer, NCB North Yorkshire Area.*

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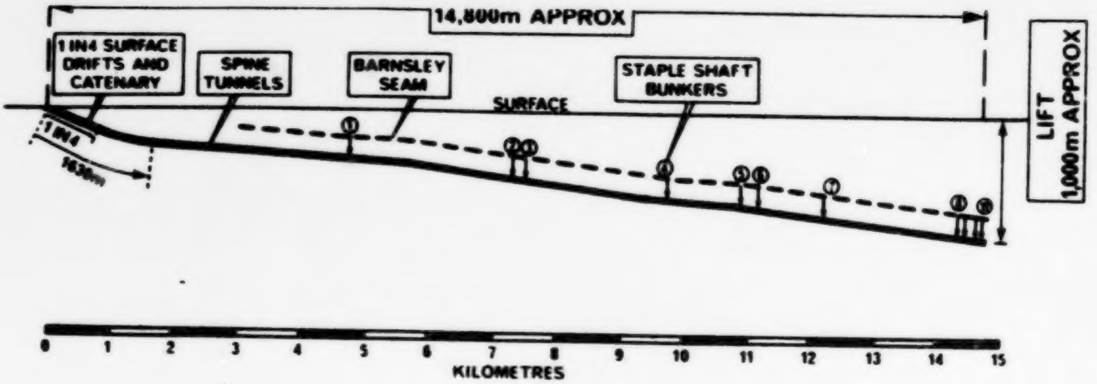

Fig. 2 Conveyor Duties

1.1 Selby Concept

The concept exploits the advantage of working the clean Barnsley Seam alone, the reserves to be worked and prepared for the market without the need for a coal preparation plant. It provides for an integrated mining concept to produce 10m tonnes of saleable coal per year, with all the mineral from the complex brought to the surface at one point outside the perimeter of the coalfield. Five satellite mine sites built within the coalfield are designed to provide ventilation, man access and materials handling to the workings. Each of the mines is managed as a separate unit. See **Figure 1**.

The key to this concept lies in the drivage of the main spine tunnels 15 kilometres across the coalfield. The spine tunnels start at the surface 70 metres apart, and dip at a gradient of 1 in 4 through the water bearing strata. In the coal measures, the tunnels continue across the coalfield at an horizon some 70 m below the Barnsley Seam. The connections between satellite mine seam workings and the spine roadways will be by eleven 7·315 m diameter vertical strata bunkers used to store the coal before it is transported to the surface along one of the spine roadway conveyors.

Within this concept for the coalfield, the drivage of the spine tunnels and the installation of the conveyor in each tunnel became the critical factor in the success of the project.

2. CONVEYOR CONCEPT

The challenge for conveying technology was to provide in each of the spine roads a conveying system capable of handling the full output. In simple terms this is 2000 tonnes per hour transported 15 000 metres, and lifted vertically 1000 metres. See **Figure 2**.

The approach to this challenge initially followed conventional lines with the specifications being evaluated for a number of conveyors in series along the spine tunnels. A detailed specification was done giving various options for conventional conveyors in tandem with underground drives and also allowing for an arrangement of Cable Belt conveyors. It became clear that there were difficulties with the installation of suitable high horsepower drives underground for the following reasons:

(a) no suitable FLP slip ring motors and control gear were available and it would be necessary to use squirrel cage rotor motors driving through high horsepower scoop trim fluid couplings operating on fire resistant fluid;
(b) due to the long distances involved there would be high power distribution losses;
(c) the drive houses for the underground conveyors would be very large excavations presenting problems, both for construction and subsequent stability;
(d) there would be particular problems with changing ropes or conveyor belting on the underground drives; and
(e) the large heat generated due to the drive energy released from the motors and gearboxes would require a substantial increase in the mine ventilation and would affect the environment in the mines if that heat was carried forward into the mine workings.

In view of these problems, the possibility of having all the drives on the surface was considered and became a prime objective for the engineering designs. To achieve this objective, the available conveyor technology had to be stretched to new limits, which are described in detail later in the paper.

2.1 Operational Concept

Further constraints on the design of the conveyors were imposed by operational concepts, and it is important that these are identified at this stage.

It is normal in most major tunnels such as the Gascoigne Wood spine roads to complete the drivage of the tunnels before the final equipping takes place and the tunnels become operational. For instance, in a major railway tunnel under the Alps, it is not feasible to run the trains through half the length of the tunnel!

At Gascoigne Wood, in order to allow production from the early mines, particularly Wistow, it was essential that the outbye end of the spine tunnels were equipped with the permanent conveyors to allow the transport of coal to the surface at Gascoigne Wood. Such a policy requires the segregation of the dirt produced in the tunnel drivages from the coal produced on the Wistow faces and developments. The policy also requires the facility for rapid extension of the spine road conveyor to keep up with the tunnelling machine, and to give access to the mine sites further along the spine roads. In no way could the final arrangement of transferring the coal from the mine workings to the spine roads via strata bunkers be available in the correct time scale for the early mine sites.

The decision to drill a 1828 mm (6ft) diameter borehole was a simple answer to this problem associated with in-seam strata bunkerage in the mine roadways at the mine above. It is likely

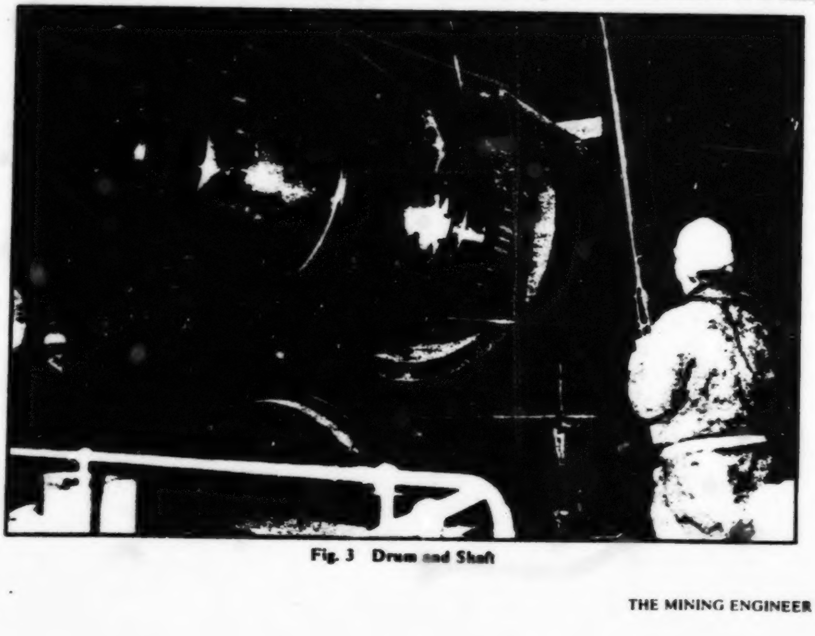

Fig. 3 Drum and Shaft

several million tonnes of run-of-mine coal have to be transported via large diameter holes onto the spine road conveyors.

When the size of the conveyor is considered alongside the operational constraints described above, it can be appreciated that the Gascoigne Wood conveyors represent a great challenge to the engineers both inside the National Coal Board and in the conveyor manufacturing companies. It is not such a surprise, therefore, that the National Coal Board decided on 7th September, 1978, to use a different type of conveyor on each of the spine roads. The remainder of this paper concentrates on the Anderson Strathclyde steel cord conveyor which is in the South Tunnel at Gascoigne Wood. A technical specification for the main features of the conveyor is included in **Appendix 1**.

2.2 Technical Features of the Conveyor

The main technical features of the conveyor are the drive, the tail end, the tensioning arrangements, the line stands and the conveyor belting. These are now discussed in more detail.

2.2.1 *The Drive*

The steel cord belting is driven through a single unlagged driving drum 2670 mm diameter at the head end of the conveyor. The drum and shaft are in the form of a single forging which weighs 90 t increased to 125 t when complete with bearings and clutches. See **Figure 3.**
3.

There are two INA double roll bearings and two 1500 mm diameter anti-run-back roller clutches. Each end of the shaft is bolted directly on to the rotors of the 5050 kW DC variable speed, thyristor controlled 'E' frame NCB type rationalised winder motors which operate at speeds from zero to 60 rpm.

Under normal operation each motor armature is supplied through its own loop by single-ended armature converters, while the fields of both machines are connected in series and fed from an antiparallel field converter. This converter provides the capability of regeneration, or if the need arose, of reversing the belt.

Links and switches are provided in the armature and field connections to enable the system to run with:

(a) Each motor armature running off its own loop control with the fields in series (normal operation).
(b) Both motor armatures connected in series supplied from one armature converter system only. This will give maximum torque half speed operation, which is the present arrangement.
(c) One motor only. This will only be possible if the conveyor loading is within the capacity of the motor power. Full speed could be achieved if required.

Supporting the main drive are numerous auxiliary motors driving pumps, fans etc. which must be brought into operation before the conveyor is started.

A non-essential supplies distribution is included, this provides power for motors for belt installation and other auxiliary items of plant.

The DC motors may be controlled from any of the control locations provided throughout the plant, but only from one location at any one time. These locations are:

- the NCB computer room,
- conveyor control room, and
- belt installation point.

All locations provide sequence start up. The belt installation point start-up will only give up to 10% conveyor speed. Additionally, the conveyor control room provides the facility of a manual start of the auxiliaries followed by a conveyor start.

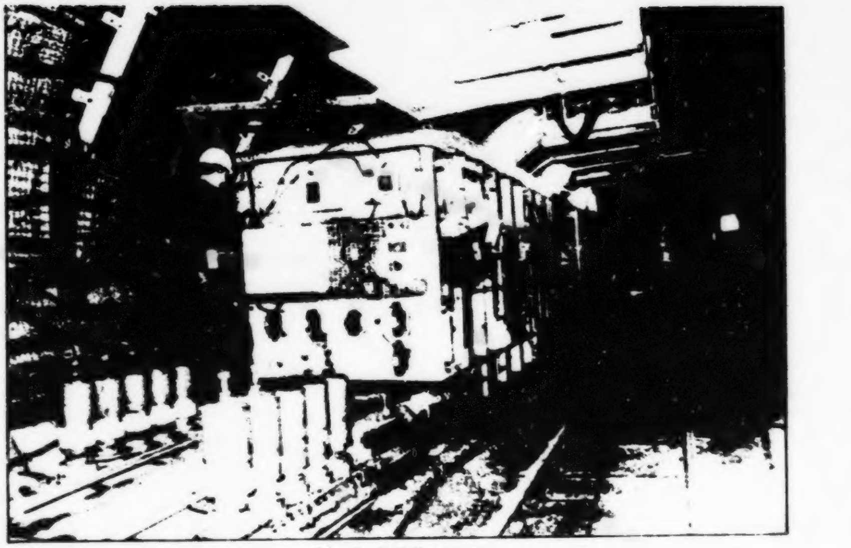
Fig. 4 Tail End Unit

The essential auxiliary motors are, in the main, duplicated to allow the plant to continue functioning in the event of an auxiliary motor failure. The auxiliaries are controlled and monitored by a GEM80 100 series industrial computer, which, on detecting an auxiliary motor failure, will automatically switch on the standby motor. The auxiliary motors may also be locally started by the operator. Remote independent control of each auxiliary motor is provided at each motor location for maintenance purposes.

Safety circuits comprising series contacts, which are complete under normal operating conditions, enable the DC circuit breaker relays and the conveyor start relays to energise. The first safety circuit proves the electrical system is healthy, the second covers all conveyor running conditions. A fault condition is indicated by a Londalert annunciator. Resetting of the safety circuits may be carried out from the control cubicle or other desk positions throughout the plant after the fault has been cleared.

2.2.2 *The Tail End*

The tail end unit comprises 1000 mm diameter pulleys built into a unit which travels along the twin continuous beams. These beams are 152 mm x 152 mm section with a cross sleeper every six metres and are lined and levelled to an accuracy of ± 25 mm. See **Figure 4**. The unit is self powered hydraulically and advances by using 'slipper grippers' acting on the continuous beams.

2.2.3 *The Tensioning Arrangements*

The belt tensioning equipment is located at the surface and at the point where it can ensure correct drive tension is maintained under all circumstances — starting, running and stopping.

This equipment, which comprises a 150 tonnes gravity weight ensures that slack belt is taken up at a rate at which it is formed during start up. Also a constant torque tensioning device maintains running tension under all conditions of loading and a locking device, to lock in belt stretch on stopping. This latter feature means that belt sag is held to a minimum and thus

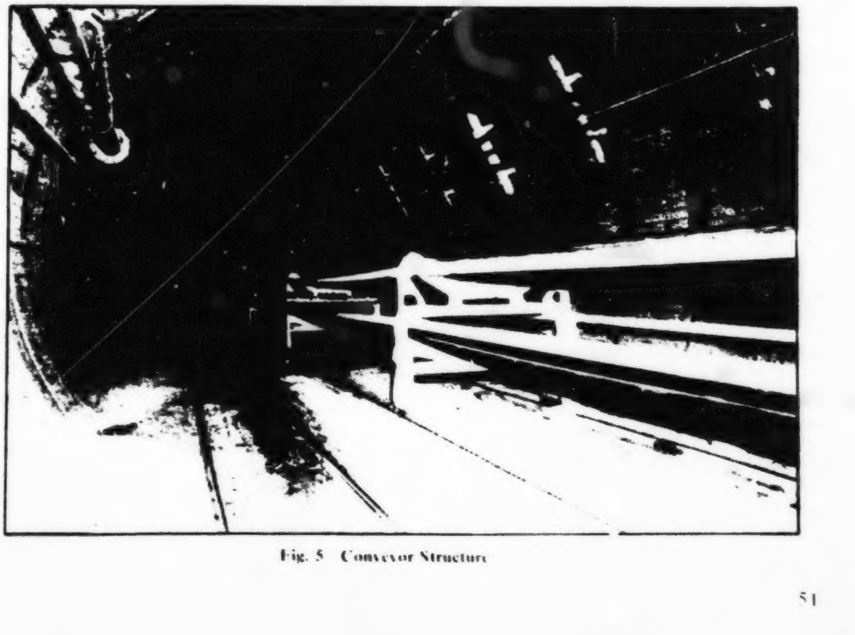
Fig. 5 Conveyor Structure

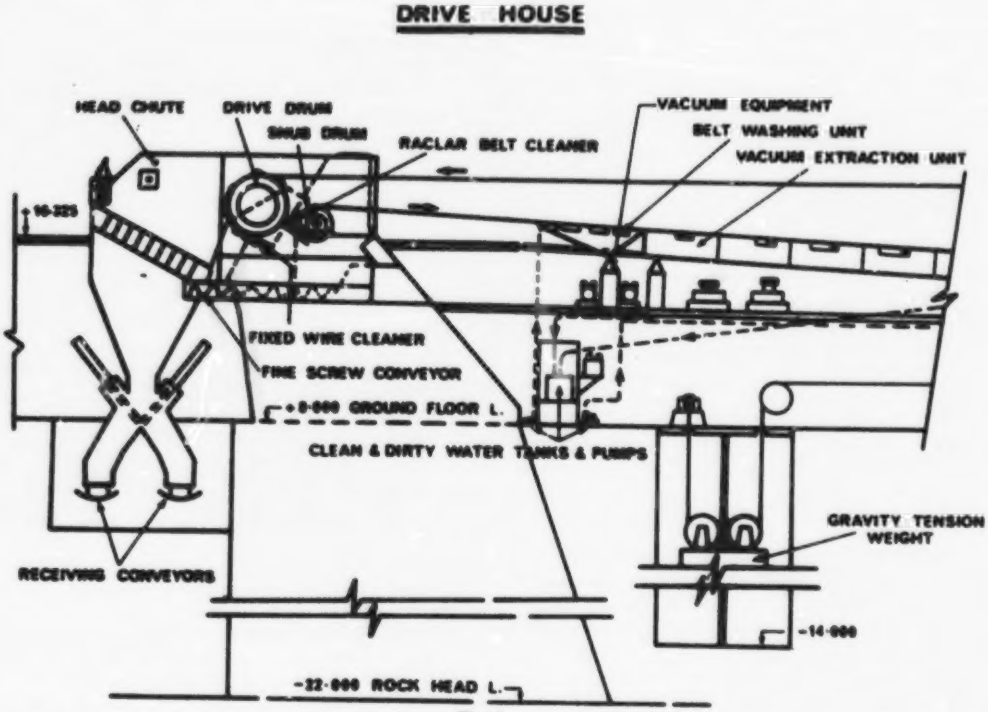

Fig. 6

overload on re-start is kept at a low level permitted by the extended acceleration time given by the DC motors.

The maintenance of all this equipment is enhanced by it being at the surface and in a suitably designed drive house.

2.2.4 The Line Stands

The idler sets are three roll 30° troughed top idlers (168 mm dia.) with two roll semi troughed return idlers. The idlers are heavy duty and manufactured to a high standard in relation to the fast maximum speed of the conveyor. This, therefore, minimises the number of sets, allowing up to 6 m pitching in the main run, closing up to 1·5 m pitching at the tail end, where it is necessary to reduce belt sag.

Both top and bottom sets are individually aligned and shimmed and, by the use of optical alignment settings, the profile of the conveyor can be maintained at a very high standard. This has considerable benefits in reducing both idler and belt wear, and permits very low operating resistance. See **Figure 5.**

2.2.5 The Conveyor Belting

The steel cord belt is 1300 mm wide x 28·3 mm thick. It is reinforced with 57 cords each 13·1 mm diameter at 22·25 mm pitch. It has a factor of safety of 5·1 and is graded ST 7100 (7100 kg/cm). It is supplied in 440 m lengths and each roll weighs 40 t. There are a total of 71 rolls of belting involved. Each roll of belting is supplied to site with factory prepared ends and all vulcanising takes place on the surface in a special prepared area. Power operated belt clamps are used as well as powered tools for cutting and paring the belt.

2.2.6 Discharge Arrangements and Drive House Design

There are some interesting features which are worthy of note in the head end designs which illustrate the scale of this single flight conveyor. See **Figure 6.**

The discharge hopper has to act as a transfer chute from the head pulley to the two collecting conveyors in the basement section of the drive house. It is carried on load cells and has a capacity of 80 t and must be able to contain all the coal discharged from the conveyor (without stopping) whilst the routing of the coal is changed on the ROM plant. This means that when the conveyor is discharging its maximum of 3250 t/h at 8·4 m/s, which is approximately 1·0 t/s; a changeover takes place in 35 s and approximately 35 t will be contained in the hopper. When the load cells register 40 t the conveyor is stopped. The hopper measures 10 m (high) x 6 m x 5 m. The 6 m length is necessary to cater for the large change in trajectory of discharge when the conveyor speed is varied between zero and 8·4 m/s.

The hopper had to be contained between the drive motors and also between the main bearing supports which are an integral part of the reinforced concrete foundations.

The foundation block is 9·75 m above floor level and extends to rock head which is 22 m below floor level. Design data supplied to the civil engineers called for the foundations to give the necessary support to the drive head without any reaction on the supports in the 1 in 4 drift. The resultant load from the drive is 1900 t acting at an angle of 7½° to the horizontal and this is established by taking into account the horizontal load of 1884 t and all the vertical loads resulting from the drive. The foundation block was constructed using diaphragm walls and contained in this section between the walls is the gravity weight pit which also extends 22 m to rock head. The length of the block (walling) supporting the drive is 18 m and extends a further 6 m to include the gravity weight pit.

2.2.7 Belt Cleaning

In order to ensure that a perfectly clean belt is returned underground so as to ensure vibration-free condition for rollers, bearings etc, belt washing has been incorporated in addition to primary scraper. + ½ mm material is removed from the head drum by a single piano wire scraper plus a Raclar multi wire scraper. These scrapers deliver material into a twin scrolled fines box which delivers into the conveyor main discharge hopper.

Within an enclosed launder, three lines of high pressure nozzles direct water onto the belt. Afterwards, a primary rotating dewatering scraper cleans off excess water followed by a bank of suction nozzles which draw off the remaining moisture. All the effluent is collected into a settling tank and, at present, clean water is drawn off and run to waste whilst the solids are disposed of by tanker. A water treatment plant is currently being constructed.

2.3 Installation of the Belt and Structure

The continuous beams required to carry the structure of the conveyor are laid on the infill behind the Robbins Tunnelling Machine as a part of the drivage contract operations. The same beams are used to carry the structure of the Dowty Meco Bunker conveyor which is used to bunker dirt from the tunnelling machine while coal is being run out on the steel cord conveyor.

The tail end unit travels along these same beams and pulls in the bottom belt as it is released from the tension carriage at the surface and fed into the drift. As the tail end advances, line stands are installed onto the beams and packed and shimmed for line and level.

All conveyor belting is introduced at the surface. During the initial installation the 440 m rolls of belting came with factory prepared ends and the 6 m long joints were vulcanised in the preparation area. This process takes about 24 hours per joint including the baking and curing of the joint. When additional lengths of belting have to be introduced, or a damaged piece removed, ends are prepared on site using the cover stripping machine and mechanical cutting equipment available at Gascoigne Wood.

The original installation was from the surface to 5000 metres and one further 200 metres extension was carried out over the pit holidays

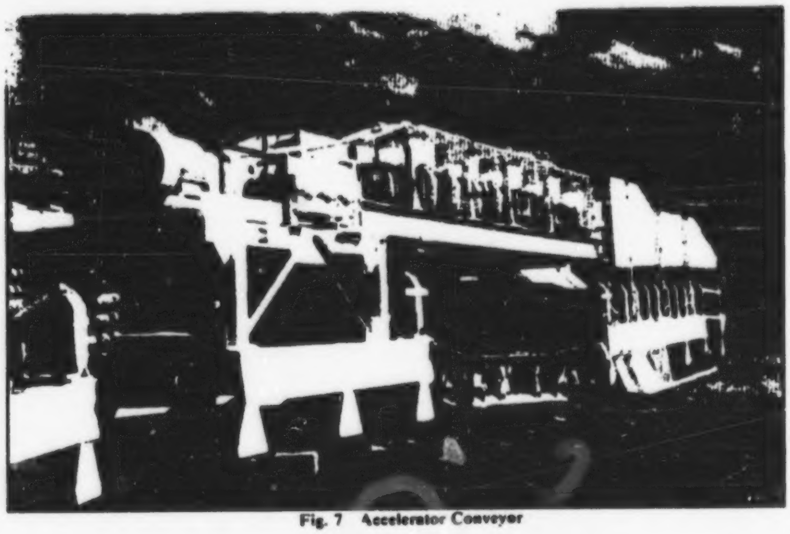

Fig. 7 Accelerator Conveyor

in August 1983. It is planned to do 200 metre extensions of the conveyor over a weekend to keep the conveyor up with the Robbins tunnelling operations. To this end, a detailed method study was done on the operations during the holiday period. This method of installation has certain advantages. It avoids the complications of taking large rolls of belt underground. Joints can, therefore, be made in a permanent location, with precise control of operations, with crane facilities and powered services for the various pieces of equipment involved. This means that factory type quality joints can be obtained with all the benefits of long life and reliability that accrue.

In addition, by combining the feature of creep speed on the drive, with the belt tensioning equipment, it is practicable to replace worn or damaged belt, all from the surface.

2.4 Accelerating Conveyor

Due to the high cost of the steel cord belting and the comparatively reduced operating factor of safety, coupled with some stringent requirements of the guarantee applied to the belting, it is considered essential to provide a very smooth transfer of material on to the main conveyor.

At each transfer point, therefore, a separate accelerating conveyor is to be installed. It is intended to use 10 of these for the 14·5 km and currently one is in operation at the first borehole. Each one will be fixed above and in line with the main conveyor and will be 6·4 m centres and fitted with a 1·05 m wide steel cord belt. The belt will be capable of operating at varying speeds and this is achieved through the 22 kW DC variable speed drive and in line gearbox. The whole unit has been designed so as to fit into the circular tunnel without additional excavation.

A prototype unit was tested at MRDE where full-scale tests were carried out on a conveyor system specially constructed to simulate the Selby system.

Video camera techniques were use to record the performance of the accelerating conveyor at speeds from zero to 6·3 m/s (three-quarters of top speed of the main conveyor, ie 8·4 m/s). At the same time the loading of the main conveyor was varied up to 2000 t/h.

As a result of these tests special discharge arrangements were designed to reduce spillage, bounce etc. and sufficient information collected to set up the first accelerator conveyor. At this moment it is running at 4·2 m/s and the main conveyor is running at 3·8 m/s, soon to be increased to 5·0 m/s. See **Figure** 7.

3. OPERATIONAL EXPERIENCE

It is early days yet to assess the performance of the conveyor but over the last few months it has certainly been tested in the range of product which it has been required to convey. The product has varied from dry dirt in the form of rock from the tunnel drivages to very wet coal from the coalface at Wistow, which could only be described as slop or swill. There is no doubt that a conveyor belt with conventional joints would have behaved much worse with the very wet product. The belt washing was also an advantage during this period.

Certain advantages of the conveyor system are already becoming evident. These can be summarised as follows:

(a) With all the drive and tensioning gear located at the surface, the major items of equipment can be installed in a properly designed drive house. This drive house can incorporate cranes and maintenance equipment that permit these units to be serviced easily and in the best possible environment.

(b) All switchgear can be non-FLP and can be located in properly designed and ventilated switchgear rooms, again with maximum ease of maintenance.

(c) Manpower requirements are kept to a minimum.

(d) A single drive conveyor lends itself to the ease of being incorporated into an overall computer controlled system.

(e) Other than the conveyor structure, supporting idlers and signals the only major items that require underground maintenance considerations are the transfer points and the tail end unit.

(f) Reliability factor is maximised with one belt, one drive pulley and two drive motors, allied to a single tensioning system.

The drive has demonstrated some special features already:

1. A slow, soft start of several minutes can be achieved, limiting the starting torque to a very low level and thus permitting lower than normal belt safety factors to be applied.

any speed up to a maximum. The advantages here are ease of belt inspection and belt maintenance, but more importantly the ability to provide a constant torque drive.

3. This latter feature means that by linking the drive into the overall computer control, the belt need only be run at that speed commensurate with the rate of loading. This reduces wear and tear on the belt, the idlers, pulleys and all other moving parts, thus usefully extending their operational lives.
4. Power consumption costs are kept to a minimum commensurate with the loadings and consequently will show considerable savings when compared to a fixed speed installation. Ramped shut-down will ensure smooth and controlled stopping of the conveyor, irrespective of the load.

It would be very wrong to imply that there have been no problems in the commissioning phase and early operations. There were the usual interface problems which exist between the numerous contractors on the site; for example, main civils, mechanical handling, electrical and cabling contractors. These problems were simplified by having Anderson Strathclyde as the one conveyor contractor. In the evolutionary design situation of the conveyor and its ancillaries, there was the ever-present ogre of redesign with its implications on cost escalation. Undoubtedly, the alignment and levelling of the beams in the tunnel to close tolerances was time-consuming in the installation period. The 'slipper gripper' system was not immediately effective, and in the interests of progress with the early installation it had to be assisted by a haulage. There have been more failures of idlers than could have been expected after the tests carried out by the makers and MRDE. Like other equipment in the Selby complex, the software and control systems did need a time after the main installation work to resolve their problems. The vague time scale of computer software problems is not easily accepted by mining engineers.

However, despite these issues, the conveyor has performed to its design parameters and all the associated equipment has done its job. The conveyor is now the single link in the chain for all conveying duties until the first length of the cable belt is installed in the North Tunnel. It is a reflection of confidence which the management has in the steel cord conveyor that the installation of the Cable Belt was started by removing the temporary conveyors in the North Drift after only a few weeks' experience with the steel cord conveyor.

4. CONCLUSIONS

These can only be regarded as initial conclusions; the final answers on reliability, cost and the economics of the steel cord conveyor will only become apparent over the next 15 to 20 years. Undoubtedly, the installation is expensive. The cost of the conveyor and the drive house will be around £40m. It must be recognised that this capital outlay has to be equated to a conveyor which is required to run 5000 hours per year and be capable of handling the average output of the whole coalfield. This output is more than the total output of most National Coal Board's Areas.

The high capital outlay should reflect in low overall costs, ease of maintenance and long life of components, including the belt. The conveyor is now at the forefront of conveying technology but during its operational life, it is reasonable to expect that mining machinery and mining techhave done over the last 15 to 20 years. The same applies to the belt. There is, therefore, a prospect that when the belt comes to the stage of being replaced, it may well be replaced with one that will be lighter and can operate with lower safety factors than would be allowable today. This means that more of the installed power could be usefully employed, permitting increased tonnages, which, combined with improved machinery and mining techniques would increase annual output in the South Drift to well in excess of those envisaged today.

Only time will answer these questions on the performance and prospects for this conveyor but the initial experience inspires confidence that this is a major technical breakthrough in conveyor technology.

VOTE OF THANKS

R. A. Bonell (Pontefract): We are very fortunate in the Midland Institute of Mining Engineers to have the Selby Project in our curtilage. This paper adds to those given on the coalfield concept with the additional benefit of some experience on this conveyor, which is one of the central outlets to achieve an overall output of 10m tonnes/year.

Within the UK mining industry, the steel cord belt is a new technique. The use of 2 x 6000 hp motor drives, with variable speed available to deal with the progressive build-up of output and the laundering method of belt cleaning are all new features. It is recognised that this is an interim review and members will look forward to further progress reports which will ultimately make comparisons of operating experience with the Cable Belt going into the North outlet.

We are very fortunate in having Mr Massey, who is a Past President of the Midland Institute and a very active member of the Institution Council and Mr John Dunn, who is a prominent member of the Institution of Mining Electrical and Mechanical Engineers, to give this well presented and most interesting paper.

It is with pleasure that I propose the vote of thanks to both authors.

P. B. Taylor (Sprotborough): In secouding this vote of thanks I feel that I ought to place on record our gratitude to the authors for taking time out from their present problems in the Selby Coalfield, which I hope will prove only temporary, to give this detailed and excellent paper today. It will form a very valuable part of the journals of the Institution. We have heard today a very detailed account of only one solution to the many highly technical problems which are facing mining engineers in this particular project, and this paper has shown the depth of detailed planning necessary in putting into practice these new concepts of mining engineering.

This detailed planning has many important spin-off advantages. One of these, and I am sure it was only time and modesty which prevented the authors mentioning it, is that the belt has been installed without a single reportable injury. It reflects great credit not only on the mine management but on the NCB engineers and manufacturers' staff involved in the project that the installation and operation of equipment of a much greater size than previously experienced in this industry has been installed without incident. I congratulate the persons involved in this for this achievement.

If modesty prevented that, I am sure it was magnanimity which prevented Mr Massey mentioning the additional problem of providing an air lock on this conveyor which was installed with the encouragement of the mines inspectorate to improve the system of ventilation of the two spine road developments.

Length of Conveyor	14·93 km
Vertical Lift	990 m
Belt Speed—Coaling	Variable 2·5 to 8·4 m/s
Belt Speed Inspection	0 to 2·5 m/s
Belt Width	1300 mm
Carrying Capacity	1828t/h from tail end, up to 3250 t/h outbye of bunker No 1
Feed Points	11, each capable of delivering 152 to 762 t/h
Installed Drive Motors	Two 'E' type DC winder motors each rated at 5050 kW
Required Power at Full Load	9500 kW
Motor Speed	0 to 60 rpm
Type of Belt	Steel Cord ST 7100
Belt Construction	28·3 mm thick, 13·3 mm dia. cords
Idler Sets	168·3 mm dia. 3 roll trough, 2 roll return
Pitch of Idlers	2·0 m at tail end increasing to 6·0 m
Tensioning Arrangement	Gravity (150 t) plus constant torque capstan
Main Drum and Shaft	2670 mm dia. drum, 1600 mm dia. Shaft single piece forging—90 t weight
Main Bend and Snub Pulleys	1500 mm dia.
Drift and Tail End Pulleys	1000 mm dia.

DISCUSSION

A. Richmond (Newcastle): The advanced technology steel cord belt conveyor being installed is, I believe, to be 1000% increase in the power of the drive to any that are operating within NCB mines. There is a 500% increase in the strength of conveyor belt and the belt speed is double that of the majority of belt conveyors. This installation is really a remarkable step forward in conveyor belt technology.

There are certain unknowns and I would wish the authors to comment. Firstly, what is the noise emission at these very high speeds? Secondly, is there a problem with the separation of material along the very long belt conveyor due to vibration? And thirdly, it has been mentioned that idlers have failed. This regardless of the quality of design is bound to happen. How is it proposed that conveyor rollers and idlers will be changed in operation?

C. T. Massey (Joint Author): Could I take the first two aspects Mr President.

First of all, noise. There is hardly any. We have run the conveyor at 100% speed, and I actually saw it running an 90% speed and the noise of the drives was negligible even at that time. On the alignment, as Mr Dunn pointed out, there is no sag along the line of the belt. It runs so quietly that sometimes we are not quite sure whether it is running or not when we are riding along on the paddy beside it. Also we have not seen any signs of separation from vibration, which is understandable as there is no vibration.

On the idlers I will let Mr Dunn comment on them.

J. Dunn (Joint Author): Yes, we have given a lot of thought to a device for changing idlers. We thought of robotics at first, but the arrangement was too sophisticated. We need to have some device which moves into position and takes the weight of the belt, because there is something like ¾ tonne on each loaded idler set. The device needs to swing into position to raise the belt such that we can slack off the complete idler set and take it out. The idlers themselves are easy to change. The selected tubes play a big part in the vibration-free running. At first we thought we might have to machine the idlers but were eventually able, by selection, to get BSC standard tube within the required tolerance.

G. Tuffs (Selby): May I add my congratulations to those proposed in the vote of thanks.

Mr Dunn mentioned the number 57, which one always associates with a mongrel of uncertain pedigree. There can be no doubt, however, that this conveying system has been developed by an organisation with a clearly defined pedigree, as illustrated by the success of the project.

Three questions to Mr Dunn:

1) Does one anticipate any separation between the wire ropes and the matrix of the conveyor belt;

2) considering the number of reverse bends during the lifetime of the belt, has the possibility of fatigue in wire ropes been considered with respect to the guaranteed life; and

3) what proportion of load in the belt is carried by the ropes?

J. Dunn: We have experienced no separation. We have had to use the technology available to us, eg BTR from Leyland also Clout in Germany. These firms were considered leaders in this field.

There will always be problems if we get corrosion in the cords hence the construction of the belt, the preparation of the splice and the protection of the belt and splice throughout the mine is of great importance. We ordered from Australia, a Harrison device and the prototype under test has so far given first-class results. We will be able to probe by magnetic techniques the heart of the cords and detect any change in condition, pick up any moisture and any change in section, etc. By running this conveyor through the unit at approximately 0·8 m/s it is possible to have a record of any part of the belt and hopefully to be able to monitor any change in condition. The results so far seen indicate that any breakaway of the cords from the matrix would be easily detected. I will be very pleased to show you graphs and charts which have been supplied by our Australian colleagues when next you are in my office Mr Tuffs.

considering its finished length of 9½ miles. The diameters of pulleys are compatible with the bending ratio of the cords, so hopefully we are not expecting any fatigue from that. Also of course the suppliers are giving us a 10-year guarantee on the belt. We may have got more but they have no experience beyond 10 years with a steel cord belt. Regarding the proportion of load taken by the cords, well it is almost totally taken by the cords. The matrix is simply to give a smooth carrying surface and to protect the cords and keep them in position. So I would say almost 90-95% of the load is taken by the cords. Incidentally, it is graded ST 7100 which means that it has a breaking strain of approximately 908 tonnes.

R. A. Bonell: The paper mentions that the steel cord conveyor was initially installed to 5000 m and that one 200 m extension has already been undertaken. What experience has been gained from that extension bearing in mind that the conveyor has to ultimately go to 15 km length?

C. T. Massey: The only comment I can make is that I don't know any better way to understand a job than to measure what you are doing in great detail. In fact, we did an extension in the August holidays which was a poor performance. But luckily we method studied it completely, and we were able to analyse all the components of work on the extension. We are fairly confident that we can sort out the problems that the method study identified, and do an extension of 200 m in a weekend behind the Robbins tunnelling machine. That is absolutely essential because otherwise we will never get the conveyor in far enough or fast enough. I must emphasise the point about measuring. If we had taken an opinion on why the job went wrong, the answer would not have been quite the same as having the real true measurements. With this sort of technology it is necessary to measure the truth; one cannot rely on opinions.

Professor J. F. Tunnicliffe (Leeds): I was going to ask a similar question to that of Mr Bonell, having been involved in the early discussions on the conveyor when we realised the extension period was a critical one in keeping the tunnelling machine going.

However, another question I would like to ask is on the subject of safety. We heard that the conveyor runs very quietly, it runs at 8·4 m per second, or can do. Has any thought been given to the fact that something moving at that kind of rate through the mine can present hazards, therefore are there any protections given to people who are walking and working in the roadways? In addition, when you look at this conveyor and the proposals relating to Cable Belt with its attendant maintenance problems are you still convinced that the right decision has been made in having different conveyors in each tunnel mainly steel cord and Cable Belt?

Do you feel that the initial capital involved with the steel cord conveyor is justified?

C. T. Massey: Can I answer that last question which is asking for a valuation and comparison between the Cable Belt and the steel cord belt. I would not give an opinion, and I would not want Mr Dunn to give an opinion on this. You will have to wait about 10 years for any answer.

We are quite happy with what we have done so far. The aim is to have a conveyor which is

to do heroics and ride at 20 miles an hour, he will be a very insane person. So I think in that respect also it should be safer.

R. G. Watt (Doncaster): Mr President sir, may I express my congratulations on what has been a splendid and fascinating paper.

The question is to Mr Dunn. What are the extent and the parameters of monitoring the conveyor state, and as the conveyor is extended towards its final length, do you see particular problems of organising response to this state indication?

J. Dunn: Thank you that's a very good question.

I was listening to a colleague giving a paper the other day and he said that on his conveyor he has 25 things that will stop it and only one to start it, and that it's shrouded and he can't get to it. This could be the case with the conveyor and Mr Massey put his finger on the button when he said the conveyor software and such control issues needed time to be resolved. Without doubt the most up-to-date monitoring techniques are being applied; we have a Gem 80/100 computer protecting the system. All the auxiliaries are protected from high temperature, low lubrication levels and so forth. One of the key issues is that all the main drive pulleys have vibration monitors fitted; I understand that the Cable Belt conveyor at Longannet has been standing for two days recently because one of the main rope wheels buckled due to bearing failure, so I am hoping that our vibration monitors will protect our very big pulleys. An example of problems with response times etc, is with pre-start warning when a signal goes out throughout the length of the conveyor and an audible signal is given. But before the conveyor starts a signal has got to be received back and proved before the conveyor can start.

We are trying to reduce some of the times necessary for some of this equipment to start but at the same time we don't want to be foolish and remove protection if at the end of the day it might save us many hours of down time. Protection is very necessary with the Cable Belt drive where traditional engineering equipment is used with a large gearbox with heavy bevel pinions, spur wheels, Koepe wheels and bearings.

P. I Allsop (Pontefract): May I first add my congratulations.

My question relates to the maintenance of the conveyor itself and the maintenance of the structure. You answered the first part in relation to the mechanism which is provided for changing the rollers whilst the conveyor is in motion. Mindful of the need for economy in manpower I wish to ask how fast does this equipment travel, because I presume it is either on the railtrack at the side, or on the conveyor structure itself. How fast does it travel and therefore what distance can it cover from the point of view of changing top and bottom rollers in the course of a shift. Do you visualise that you will have to have more than one set of equipment.

The second point is that I do firmly believe that the monitoring of all the equipment at the head end and the tail end, being engineering parts, will have been extremely well done and will not be a problem. However, the conveyor

in how one would be able to monitor the whole of the conveyor length when it gets to 15 000 m. So the question essentially is, what thoughts are there for monitoring the state of all the conveyor rollers? I appreciate that one couldn't monitor each individual idler set because it would be far too expensive, but are there any thoughts about ways in which batches could be monitored so that extensive damage to the belt could be avoided by not having failed idlers?

J. Dunn: Thank you, all very good questions Mr Allsop.

Can I start—I want to be very careful about this device for changing idlers, when the conveyor is running. We were full of enthusiasm as you know and started off with all sorts of ideas but we will start with a hand-operated unit, with a hand-pump and jack before we move on.

We were debating having a device which was self-propelled with its own engine but with the concentration of effort in this tunnel at the moment, it is not possible to occupy the track alongside the conveyor for any length of time. I am pleased to say that we did consider monitoring the performance of each idler but there are approximately 13 000 idler rollers in the finished job. We found that the anticipated rate of failure of the transducers monitoring the idlers is something like ½%, so the man in the control room could be receiving rogue signals saying that some 10 idlers had failed. We have got a Fenner device on test now which is an infra red device which detects small degrees of temperature rise. If we stop the conveyor for three minutes to allow the defective idler to transmit its heat into the belt, this unit on the surface will indicate the hot spot. The device is looking good but we need to determine what, if any, heat is transferred through the steel cords. On the question of manpower, we are constantly battling alongside Mr Massey to maintain manpower levels where they ought to be, or Selby will not be the magnificent place it should be.

D. Summerfield (Barnsley): You have stressed the importance of sensors both at the drive head and at the return end of the conveyor. You also mentioned the critical importance of ensuring the correct line and level of the conveyor. With this latter thought in mind I can imagine that a conveyor of this specification travelling at some 20 mph wouldn't have any difficulty cutting through any line stand it came into contact with.

Could the authors indicate if there is any intention of monitoring the line and level of the conveyor throughout its entire length so that any movement to the structure resulting from roadway distortion is detected before any damage is caused.

J. Dunn: That is a very good point and we were worried about it since lining and levelling gave us a lot of work. The colliery surveyors put a line along the full length of the tunnel and Anderson Strathclyde used an optical alignment instrument for cross levelling etc. The dimensions were all marked on a plan and individual steel packs were made and placed between the base of the line stand and the carrying beams. After five months' operation we checked the line again and we found that there are very few areas where we have something like 12 to 40 mm drop and we are now able to move into these areas and re-pack, but for 90% there has been no movement over the last six months.

THE CABLE BELT CONVEYOR AT SELBY MINE

Ian M Thomson
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SUMMARY

The 10 million tonnes per year Selby Mine Complex of 5 mines has coal transportation centralised on two parallel 15 km surface drifts. One of these is equipped with a single flight CABLE BELT conveyor with the highest power installed to date. The principal design problems and solutions are outlined, in particular highlighting differences between this installation and previous conveyors purchased by the United Kingdom National Coal Board.

The design concepts and details of the 8500 kW drive unit and its torque responsive braking system are described.

THE CABLE BELT CONVEYOR AT SELBY MINE

During the 1960's the United Kingdom National Coal Board carried out an extensive exploration programme and in 1973 proved that there were new reserves of over 600 million tons of extractable coal located in the Barnsley seams of the North Yorkshire coalfield in areas outside the traditional coal fields. The existence of this eastward extension of the traditional Barnsley seam of the Yorkshire coalfield beyond the North/South fault had long been suspected but it was not until the completion of this exploration programme that the size and structure of the coal reserves was fully appreciated.

This coalfield consists of several seams, the Main seam averaging 1.2 metres to 3.3 metres thick. At the western extremity the seams are located at a depth of 300m gradually pitching to the east at an inclination of 1:17 to a maximum depth of 990m. To the south the field is bounded by a major fault. To the east the coal field appears to extend and form part of the N.E coalfield which extends under a large part of the southern North Sea, but at depths not workable by conventional coal mining techniques.

Due to the necessity of developing this new coal field without incorporating radically new technology it was decided that the Selby Mine Complex as it became known would be restricted to an area of 259 sq. kms with extractable reserves of 600 million tons.

The development of the Selby Mine Complex is a key element in the National Coal Board's "Plan for Coal" investment programme to replace near-exhausted and uneconomic mines with larger, high productivity new mines.

This complex was to be developed as 5 separate mines which would have a common underground transportation system to produce up to 10 million tons of coal per year delivered to a new rail loading facility at Gascoigne Wood located near Selby in Yorkshire. From this point the coal would be transported over the existing rail network to its customers, principally the Central Electricity Generating Board. As the coalfield is located under a low lying river landscape, a mining plan had to be devised to ensure that surface subsidence was minimised over the whole area and in particular in the area of the town of Selby where there is an historically important 12th century abbey. The plan eventually adopted led to the building of 5 mines at Wistow, Stilling Fleet, Ricall, North Selby and Whitemoor which were equipped with vertical shafts for transporting men and materials only, whilst the coal transport from all of the mines would be by means of two parallel inclined drifts which would be located under the coal seams.

As illustrated in fig. 1 the mines were located at the most convenient point for their area of the coalfield and the coal from each was to be transported "in seam" to the parallel inclined drifts located 60m under the coal reserves. In all there were to be 11 loading points to each inclined drift with 1500t bunkers at each point to allow a degree of storage between the mining operations and the trunk transportation system.

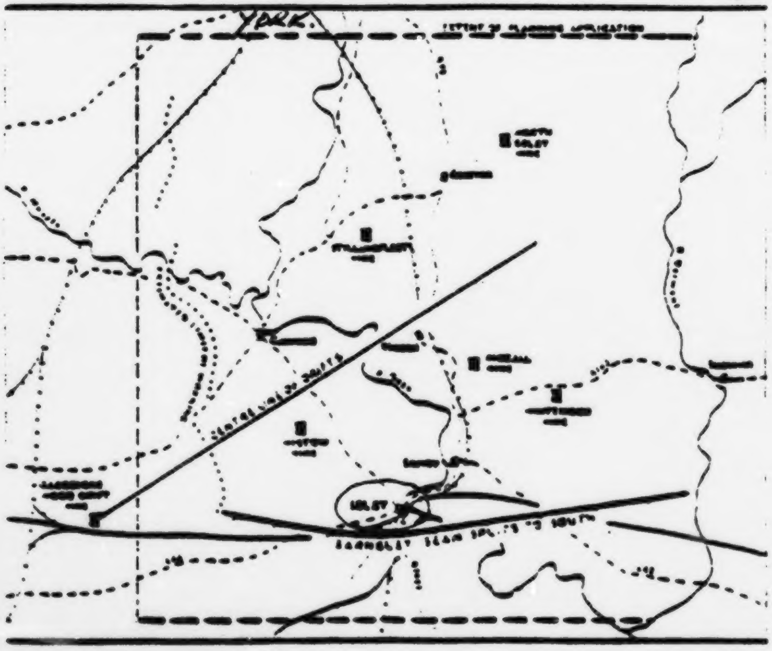

fig. 1

This concept is very similar to that first used by the National Coal Board at their Longannet Mine Complex in 1968 where three separate mines employed a single central coal transportation system to deliver coal into the Longannet Generating Station.

In that installation a 4.8m x 3.6m gallery was driven under the coal reserves and a single flight CABLE BELT conveyor was installed drawing coal from 4 loading points. This system has recently completed 12 years of successful operation and is a forerunner of the Selby Mine Complex, with many of its features being directly translated into the Selby Mine. These included variable speed operation of the trunk conveyor, computerised control of the bunker loading facilities, as well as computerised blending of the coal from the different mines to ensure optimum ash content. As can be seen from fig. 2 there is a remarkable similarity in the concepts used at Longannet and Selby.

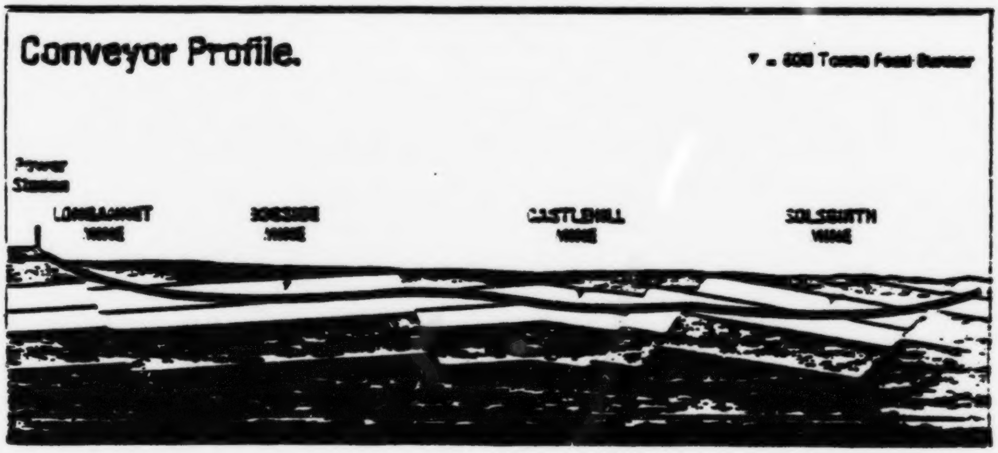

fig. 2

In 1978 the National Coal Board invited tenders for the supply of conveyor systems to be installed in the North and South Drifts. Both applications were to be identical as the intention was that each conveyor would normally handle half of the output but either system had to be able to handle the whole of the 10 million tonnes annual output.

Realising that any conveyor system would be at the limits of the then current conveyor technology, the National Coal Board looked at various solutions, but the primary criteria laid down were :-

a) A single flight system, if possible, would be preferred.

b) The use of new or unproven technology to be avoided as far as possible.

c) The conveyor had to be able to handle the worst loading condition, which was to transport 1830 tph from the farther-most loading point located at 14920m from the discharge point.

d) The belt width had to be suitable for a variety of other loading conditions due to the possible loading rate combinations from the other bunkers up to a maximum of 2800 tph.

After evaluating several alternatives the National Coal Board elected to place separate orders for the North and South Drift and in September 1978 an order was placed with Cable Belt Ltd., for the design, manufacture, supply and installation of a complete single flight CABLE BELT conveyor in the North Drift.

This contract was valued at 1978 prices, at approximately £10.8 million. In the intervening period, whilst there have been no significant technical changes or additions, there has been significant inflation which will bring the eventual contract price, when the installation is complete, to £16 million.

Whilst this CABLE BELT conveyor obviously had differences from the CABLE BELT conveyors supplied previously, these were mainly of size and the detail engineering that flowed from that. All the design factors, parameters and practices, were in large part the same as those that were used in the previous installations.

This considerably reduced the risks and clearly identified the few areas where new technology, factors and design standards were required.

It was decided that in the case of the system design, no new factors or practices would be used at all. The conveyor friction factors, acceleration factors used in catenary design, and power calculation factors were all those used in the CABLE BELT conveyors (87 in all) purchased and operated by the National Coal Board.

Due to the high tensions involved the only concession made in the system design was that a maximum speed of 7.62m/sec., would be adopted which was about 50% higher than CABLE BELT conveyors actually in operation, and about 25% more than two CABLE BELT conveyors that were then under construction and have now been commissioned.

As a result the system characteristics were eventually decided and are as shown in table 1.

System Characteristics

Length	14923
Lift	990
Capacity	1830 tph (from tailend)
Belt Speed	7.62 m/s
Belt Width	1050 mm
Drive Cable diameter	57 mm
Drive Cable Breaking Load	240 tonne
Factor of Safety	3.1
Line Pulley Pitch Top	4 m
Line Pulley Pitch Return	8 m
Drive Wheel Diameter	6.7 m
Loaded HP at full speed (at 1830 tph from tailend)	8173 Kw
Installed Power	8750 Kw
Empty HP at full speed	2080 Kw
Type of Surface Arrangement	Head Discharge

table 1

Figure 3 shows the arrangement of the various loading points and it is interesting to see from table 1 that the maximum required power is at a loading rate of 1830 tph from Bunker 11.

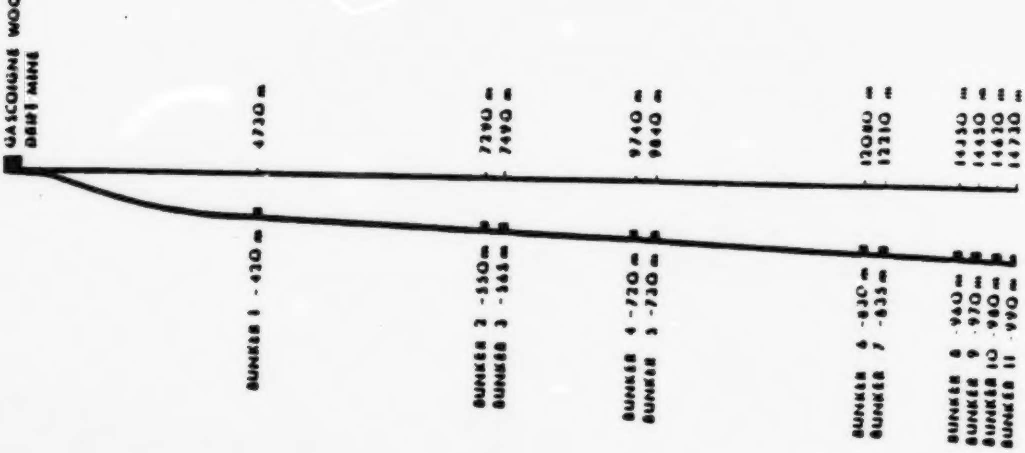

fig. 3

The other table 2 also shows clearly the capacity that this power can carry from each of the other loading points ranging from 1830 tph when loaded to the full length of the conveyor, up to 4420 tph when loaded only from the first loading point, Bunker 1, with the rest of the conveyor empty. Obviously there are many other possible combinations of capacities with varying feeds from the 11 bunkers but the maximum power and rating is the 1830 tph for the whole length of the conveyor

The conveyor is at its most efficient when fully loaded at its maxiumum capacity of 1830 tph from bunker 11 where the power consumption per tonne lifted to the surface is 4.47 Kw equivalent to 0.30 Kw per tonne/km. At all other loading conditions it is less efficient (due to the power consumption in running the conveyor empty at full speed) and the power consumption per tonne will be higher.

Power consumption, and efficiency is at its lowest, when running empty when it absorbs 2080 Kw.

Bunker No	Capacity when loaded only from bunker using maximum horsepower available
1	4420
3	3212
5	2483
7	2136
11	1830

Table 2

Of the main equipment for the conveyor there were many items which were standard Cable Belt items that only required minor modification to suit this duty.

These in the main were :-

Belt
Linestands

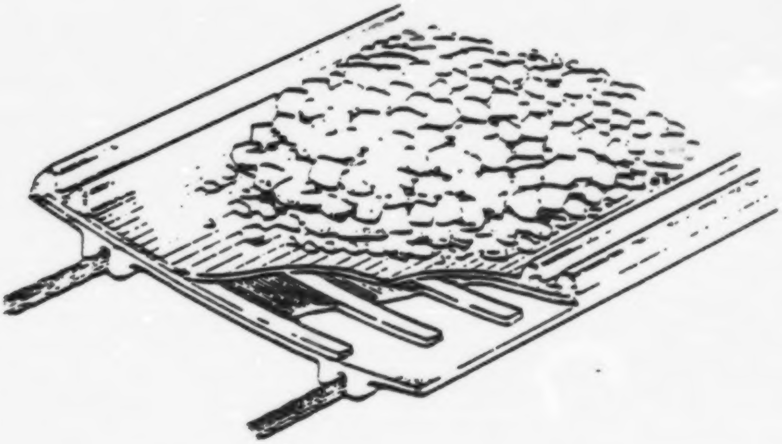

fig. 4

Fig. 4 shows the neoprene based belt construction which is the normal Cable Belt construction used by the National Coal Board It was not felt that any special features, such as extra cover thickness needed to be included as the NCB experience with this belt over a long period was that a life of 15 years should be easily achieved. Their experience indicated that based on the average life obtained on all of their installations, a life could be achieved considerably in excess of this.

It is worth noting that this belt as well as meeting the normal NCB specification 158 (1980) fire resistant specification covering items such as anti static properties and flame tests, also had to meet the new European belt standard for the propane burner gallery test. In this test the NCB adopted the more severe version of this test.

The type of linestand adopted is shown in fig. 5 and is the normal linestand with 4 pulleys on the top line at every linestand and 4 pulleys on the return line every second linestand.

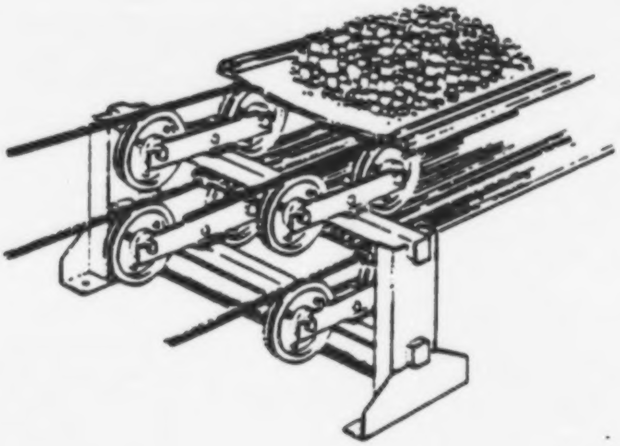

fig. 5

Typical 8 Pulley Linestand

This linestand and rocker arrangement caters for the various misalignments that will undoubtedly occur in an underground operation. Misalignments in all three planes are catered for in the main by automatic adjustment and only for large misalignments will require manual adjustment.

The drive cable is a normal Langs lay 6 x 19 round strand I.W.R.C. rope with the following design :-

Nominal diameter	57 mm
Breaking Load	240 tonne
Outer Wire diameter	3.7 mm
Steel Grade	180
Strand Construction	6x19 (12/6 x 6F/1) IWRC
Core Construction	Steel

This, at the time was a slightly larger diameter than any other operating CABLE BELT and therefore it was extensively tested to ensure that the same operating performance would be obtained as in the 51mm ropes already successfully in use.

This testing covered a full range of bending fatigue, tensile and friction coefficient tests as well as full scale testing of the splices. During this testing it was confirmed that the normal type of splice, but of a length of 60 metres, was suitable. It is interesting that in two conveyors recently commissioned, with this size of cable, the field splicing only took 10 hours per splice.

Because of the relatively high speed and the larger rope diameter it was decided to make a POLYRIM pulley with a slightly larger tread groove diameter, 300mm against 270 mm, than the standard pulley, with a deeper polyurethane tread substantially increasing the POLYRIM life.

Other than this change the basic design as outlined in fig. 6 is similar to the standard POLYRIM pulleys used on all other CABLE BELT installations.

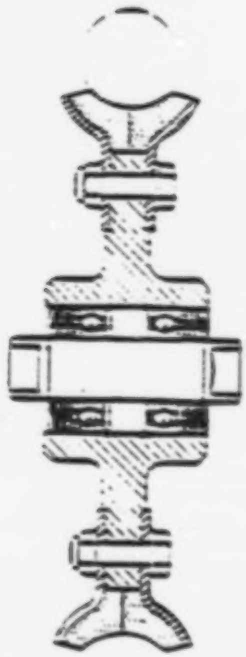

fig. 6

The single item in the conveyor system which required a completely new design was the Drive Unit. The National Coal Board decided that, despite the substantial extra cost they preferred 60 rpm DC electric motors made generally to their standard Mine Winder design. This necessitated the complete redesign of a single reduction Drive Unit which still had to contain a differential.

Due to size of the equipment and the torques and loads that had to be transmitted it was designed as a single reduction set with the differential gear mounted on the input shaft driving both of the final gear wheels. The complete gear train is supported on a substantial ring beam. The main drive casing is not used as a support for the gears but is in effect an oil bath for the gears and bearings.

The high torques and loads experienced on the drive unit advanced the design concepts to new fields regarding fatigue considerations.

The input shaft, housing the differential assembly weighs some 95 tonnes and is preassembled prior to installation into the drive unit. The shaft itself is 7m long and up to 1.2m diameter.

The first motion pinions, are 2.3m diameter with a face width of 0.72m and the differential wheels which together with the differential pinions and carrier complete the first motion shaft assembly, are 2.77m diameter having a face width of 0.46m.

The 5m long final shafts fully assembled weigh 97 tonnes each and comprise a gear wheel and koepe wheel on each shaft. The shaft weighs 29 tonnes and has a maximum diameter of 1.13m, designed to give a maximum deflection under full load of 0.15mm. The final gear has a face width of 0.72m and is 6.23m diameter whilst the koepe wheel incorporating a braking path on its outer most periphery is approximately the same diameter as the final gear.

In order to keep the tread pressure on the drive wheel within acceptable proven limits a diameter of 6.7m was required for the two koepe wheels. The tread lining is the Cable Belt standard polyurethane composite material giving friction coefficients in excess of 0.30 even under wet and oily conditions.

All the shafts of the drive units are supported in split roller pedestal bearings located directly on to the heavy fabricated steel ring beam and outboard base frames all mounted on a concrete plinth.

The lubrication of the gears is by a positive displacement spray system over the full face width of the gears and for safety each spray nozzle is individually monitored for flow and pressure. Becuase of their low rotational speed the pedestal bearing are greased.

Drive is transmitted from the motors to the drive unit via double engagement gear couplings.

It can be seen from fig. 7 that whilst the equipment is larger it follows the general pattern of the other Cable Belt drive units.

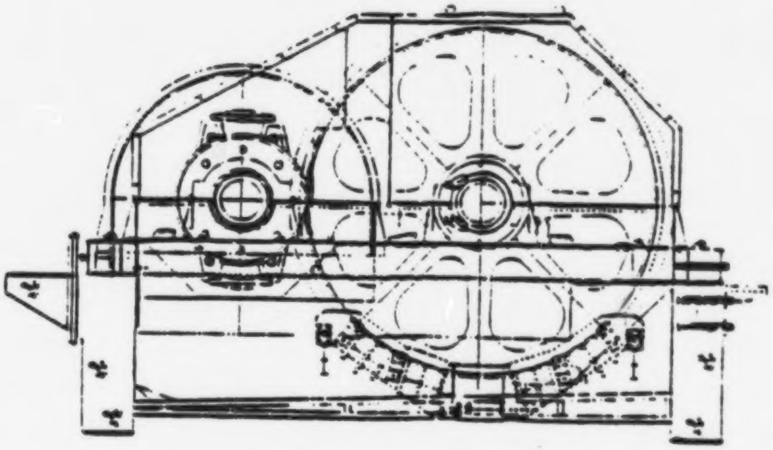

fig. 7

As there are very high runback torques particular attention was paid to the braking arrangements, and in common with most of the other large inclined drift CABLE BELT conveyors that have been built, disc brakes incorporated into the final drive wheels are used as standard. These brakes are of the torque responsive type, not being released until the drive motors have built up sufficient torque to overcome the conveyor runback load. Sprag clutches or similar non return devices are not now used on CABLE BELT conveyors.

Four double caliper brake units are arranged to act directly onto each Koepe Wheel rim. The calipers are mounted on a brake frame assembly mounted below each wheel. Braking loads are detected by load cells and the brakes are not released until sufficient driving torque is available. The brakes are partially applied at a small percentage speed whilst the conveyor is stopping naturally, and fully applied when completely stopped.

The brakes are fail safe, in that they are spring applied and hydraulically released.

The tension is applied both to the drive cables and the belt at the tail end of the conveyor and is of a gravity type operated by means of a weighted drive cable carriage. It is simple and is contained within the normal confines of the drift.

The design of the other ancillary mechanical equipment was straightforward, with the main exception being the use of variable speed accelerating conveyors at the loading points. Subsequent testing of these accelerating conveyors, which were added to the original proposal instead of chutes, has shown that they have no advantage over correctly designed chutes and may even be less satisfactory.

The drive motors and control gear are generally to the standard D frame series NCB 60 rpm mine winder DC motor complete with thyristor control giving a completely variable conveyor speed from 0 - 7.62m/sec.

The safety monitoring system along the length of the conveyor utilises standard pullkeys and the standard Cable Belt detection devices at intervals of 90 metres.

Fig. 8 also shows the extent of the buildings necessary for such a unit and it can be clearly seen that less than 50% of the area is required for the CABLE BELT drive and Discharge arrangements the rest is merely required for aesthetic reasons or to contain the men and materials haulage.

Due to delays in the driving of the drifts the project which had been scheduled to have Phase 1 (5 km) operational by March 1982 has now been delayed to January 1984 with the final extension to the full length of 14.9 km being delayed from December 1984 to December 1986.

The general arrangement of the discharge point shown in fig. 3 which is of the Head Discharge type to allow separation of the electrical drive system from the coal discharge point.

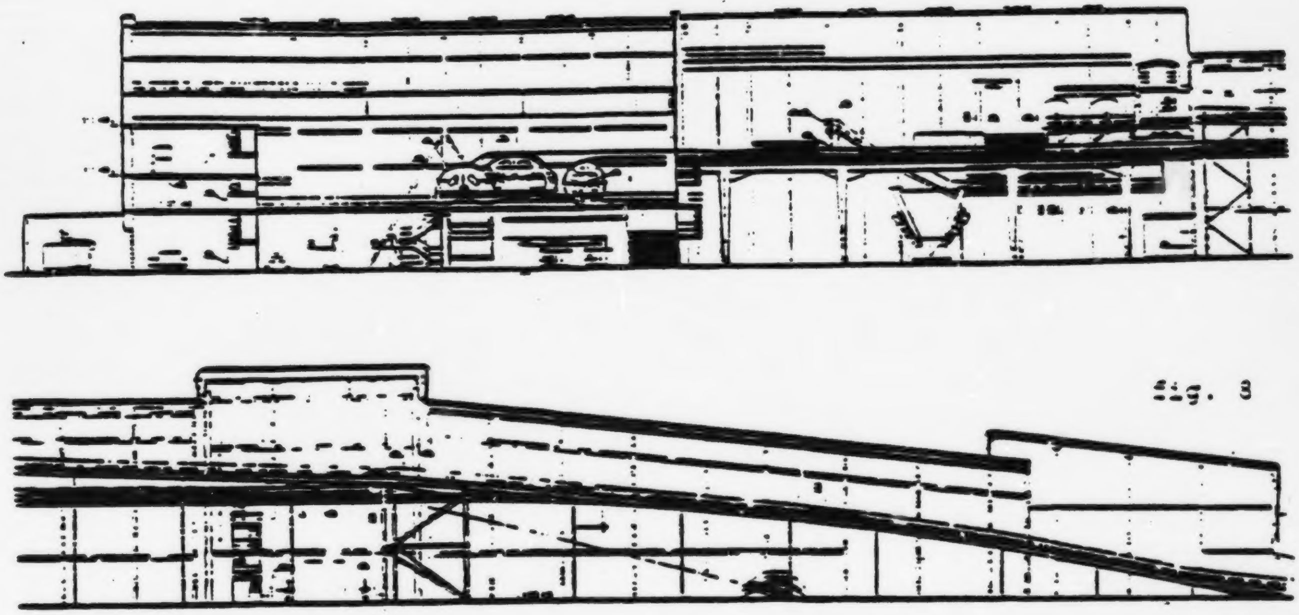

fig. 3

Apart from the size of the individual components most of which are now in use on a 52 kms conveyor system. There were no significant problems on the design or manufacture of this equipment.

Particular attention was paid to the belt cleaning which is of the combined scraper and rotary brush type. Belt washing is not felt to be necessary. In order to make maintenance of the discharge point easier the discharge equipment was mounted on a platform of reinforced concrete, with a lower platform in the area of the belt cleaning equipment for access. Fine material removed from the belt is fed by a scraper chain conveyor into the main hopper.

One possible advantage is that all of the Selby equipment, which is now available on site ready for installation, has already been in use at other installations, particularly at the 52 km CABLE BELT conveyor in Australia which although ordered after the Selby project has in fact now been fully commissioned.

We now have clear evidence that all of the equipment at Selby, with the exception of the Drive Unit which is unique, operates as designed.

The Author would like to thank the North Yorkshire Area National Coal Board and members of the Major Projects Group of the National Coal Board for their help in preparing this paper.

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MONITORING AND CONTROL OF CONVEYORS AND HAULAGES

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SYNOPSIS

The paper discusses the type of transport systems used in British mines and examines the safety of such systems; it recognises the need for effective means of control to improve safety and productivity. The authors analyse the requirements for the control of both endless-rope haulages and conveyors. The techniques applied to the design of signalling and communication systems are outlined including the utilisation of the communications system for pre-start warning on both haulages and conveyors. The authors discuss the techniques which are applied to monitor the transducers which are associated with the transport equipment. Comprehensive systems which combine the function of signalling, communications, pre-start warning and transducer monitoring in a single integrated unit are also covered. They continue by discussing the techniques employed for the remote control of plant and the concept of the underground control and monitoring system is introduced. Finally, the paper covers surface control of underground conveyors and plant by means of mini-computer and micro-processor based systems. The authors conclude by describing systems which provide distributed intelligence and summarise the improvements in productivity which can be obtained from the provision of modern control and monitoring systems.

Introduction

In recent years, the operation of underground transportation systems has assumed a new importance in the quest for safety and productivity in mines. In the United Kingdom the transport of men, material and mineral is achieved largely by the use of conveyors and rope haulage systems as can be seen from Table 1

TABLE 1 - Transportation Systems

Type of System	Total Number	Used for Men
Rope Haulage	8300	388
Loco Haulage	879	185
Captive Rail	100	30
Conveyors	6000	765
Mono-rail	100	---
Rubber Tyred	230	3

The average distance from face to shaft-bottom in British Mines is 3.8km and it is a fact that many British miners travel further underground to their place of work than the distance travelled between their home and the mine.

In 1980 the average travelling time per shift was 90 minutes, to bring about further increases in productivity, this travelling time must be reduced by the introduction of faster man-riding transportation systems and safer more effective means of control.

Due to the distance between the coal face and the pit bottom (likely to average 5km by 1985) the safe and efficient transport of men, materials and minerals is a major factor in bringing about further improvements in safety and productivity.

Safety

In 1981 16 men were killed and 239 men received serious injuries in accidents associated with underground transport system in U.K. mines. These figures account for 35% of all underground accidents. Table 2 gives comparative figures for the five years 1977 to 1981.

TABLE 2

Year	Underground Haulage and Transport-Related Accidents	% of all Underground Accidents	Total of all Underground Accidents
1981	255	35	723
1980	182	37	484
1979	144	34	416
1978	191	40	473
1977	189	39	478

An analysis of these figures shows that most transport-related accidents occur on rope haulages and conveyors. See Table 3.

TABLE 3 - Transport-related Accidents on Mine Roads

Location	1977	1978	1979	1980	1981
Rope hauled haulage system	89	92	64	99	105
Roadway Conveyors	27	32	25	29	43
Total on Mine Roads	163	167	116	148	206
Total Underground	189	191	144	182	255

It is perhaps inevitable that when high-powered moving machinery is used in confined spaces underground, accidents will occur. Much has been done to minimise this risk; however, there is much more that can be achieved by careful overall system design and implementation of safe working practices.

Operation of Haulages

As can be seen from Table 3, accidents on rope haulage systems account for the highest number of transport-related accidents. To minimise the risk of such accidents on haulage systems it is necessary to ensure adequate standards are maintained for the mine roadway and haulage track and that the haulage is adequately monitored. An additional precaution is to ensure that men do not need to accompany the haulage.

In the U.K. special regulations were issued in 1971 to cover the remote control of haulages. These regulations were particularly exacting; a summary of the requirements is as follows:

i. Provision of adequate roadway clearances and a high standard of track maintenance.

ii. Means to detect and extinguish fires.

iii. Protection and monitoring of the haulage apparatus to ensure safety in the event of an electrical or mechanical failure.

The remote control of haulages can be achieved by direct-wire techniques or radio control. Recent developments in the field of motor-speed control allow greater use of more sophisticated remote control systems. A further aid to safety in the operation of haulages is the concept of the despatch and receive system to ensure that haulage workers are not exposed to the hazards of accompanying haulage vehicles.

A despatch and receive system ensures that the haulage train is attached to the rope by a special clip-car and that the position of the haulage is effectively monitored in the mine roadway. Safety gates prevent access to the haulage road when the haulage is in use and aspect lights provide visual warning to workers, see Figure 1.

In cases where a man-riding conveyor is installed in the haulage roadway, the two items of plant are interlocked to ensure that the haulage cannot operate if the conveyor is running and vice-versa.

The minimum requirements to operate a haulage are the provision of a fail-safe signalling system allowing workers to stop the haulage from any point along its length. In the case of man-riding haulages this system may be a simple bare wire signalling system or a sophisticated radio signalling system. However, it is a mandatory requirement that an emergency stop system is provided throughout the length of the roadway for all types of haulage.

The haulage must be monitored to detect electrical and mechanical faults and typically the following transducers are provided:

- overspeed
- rope over-tension
- broken wire
- rope slip
- broken strand
- over-travel (forward)
- over-travel (reverse)
- brake wear
- brake temperature
- thruster brake wear
- thruster brake temperature
- thruster brake on
- thruster brake off
- temperature

In the case of over-travel it is necessary to provide back-out facilities to ensure that in the event of over-travel of the haulage, it is possible to over-ride the limit switch and operate the haulage in the opposite direction.

Pre-start warning systems, although not mandatory, can provide further significant improvements in safety.

Operation of Conveyors

Safe operation of conveyors is perhaps easier to implement than safe operation of haulages.

A fundamental requirement is the provision of a fail-safe signalling system allowing workers to stop the conveyor from any point along its length. Many types of system are available, but these should not be used as a substitute for isolating the conveyor motor during important maintenance work.

Pre-start warning systems are now commonplace on conveyors underground. It is common practice to broadcast pre-start warning tones from loudspeaker amplifiers installed along the mine roadway. This loudspeaker system also serves as a communication system - an important aid to increased productivity.

Transducers and monitoring systems are widely used to ensure safe operation of the conveyor drive and to detect dangerous conditions such as belt slip, torn belt, belt misalignment or blocked chute.

Further increases in the safe operation of conveyors are likely to be achieved by improvements in transducer design coupled with a greater use of monitoring systems and perhaps more significantly by upgrading more conveyors to man-riding status to reduce the problem of illegal man-riding. A further factor is the improved design of conveyor chutes to eliminate spillage at transfer points. The introduction of remote control and automation systems has focused attention on this latter point.

Signalling Systems

Signalling systems are required to provide a highly reliable method for stopping the controlled plant. Basically signalling systems take the form of an extended control loop or lock-out circuit along the length of a conveyor or haulage system. Techniques have to be used to make this loop fail-safe from the point of view of cable faults. Open circuit is inherently safe if a chain of normally closed switches connected in series is used but it is necessary to protect against short circuit conditions that would make inoperative any switches beyond the fault.

One common way to overcome the problem is to connect a semiconductor diode into the control loop; physically this would be positioned at the remote end of the system. Control circuits can detect the presence of this component which allows action to be taken in the event of short circuit faults on the cable. An alternative method is to have an oscillator at the remote end of the control loop; the control circuits can then monitor the operation of the oscillator. This method has some advantages particularly on longer systems though it is important to ensure that the control loop cannot be simulated by other fault conditions. For instance, there could be some pick-up between the oscillator supply current and the lock-out line; in the event of an open circuit on the lock-out line this pick-up must be too small to be recognised as a healthy state by the control circuitry.

An enhancement required of many signalling systems is the indication of the lock-out position along the length of the conveyor or haulage. A number of techniques have been utilised for this, some of which need extra cores in the cable along the system. For short systems a digital method is probably the most effective, particularly if the environmental problems are quite severe. These systems involve having an electronic circuit in each key which produces an output pulse at the appropriate time. Pulse-counting circuits at the control point identify the location of keys that are locked-out by monitoring the existence of these pulses. This technique usually involves extra cores in the cable which has disadvantages on longer conveyors, both from the additional cost of the extra cores involved and the difficulties associated with supplying power for all the key circuits.

Other methods that are used to overcome these problems involve special circuits in the control unit that either produce a stable constant current or constant voltage which is used to interrogate resistive elements in each key. In the first case the resistive elements are in series and the voltage across them to the point of lock-out is measured, in the second case the resistance elements are connected in parallel and the total current to the point of lock-out is measured. Both systems can be made to work on well installed systems in a good environment though they are not tolerant to changing shunt or series impedances whether caused by the environment or inadequate installation.

A similar technique can be used that provides for greater immunity to shunt or series impedance change this involves putting a circuit in each key to provide the control of shunt current in place of the parallel resistor. This means that the current generated by a key is largely unaffected by the voltage across it, which enables higher currents to be used than in the case where parallel connected resistors are used because voltage drop along the system is not important. The higher current allows considerable variation in cable shunt impedances without affecting system performance. Series impedance variations alter the voltage drops throughout the system and providing these are not too great to prevent the circuit in a key from operating then the system accuracy is not affected. This type of system adds more cost to each key but provides significantly improved operational performance. The components of a typical system providing these facilities are shown in Figure 2.

Communication Systems

Roadway loudspeaker systems have been in use for many years; they provide a reliable means of communication both along the roadway and to a surface control room. The systems consist of a number of amplifiers linked together and powered from a common power supply unit normally located at the drive unit. Facilities and techniques have evolved over the years so that there are many similarities between equipment of different manufacturers.

The number of amplifier units that can be supplied from a power supply unit is typically a maximum of twenty, each amplifier has the facility for initiating a call tone, along with a press-to-speak button for normal speech communications. These systems often have the facility for extending the audio connection to the surface where it can be terminated in a surface exchange unit. Calls to the surface can be initiated from an underground amplifier by means of the call tone, with some systems a single call tone is used for calling both the surface exchange and for local calling, the difference being the duration of the call-tone, other systems use separate call tones for surface and local applications.

The communications facility is an aid to greater productivity; the ability to inform people, at the surface or workplace, of problems minimises operational delays. Another important aspect of these communication systems which improves the operational safety of conveyors and haulages is the ability to provide an audible pre-start warning along the length of the system. For some types of plant it is mandatory that such a system is used. In other cases, if a communication system exists then pre-start warning may be added at minimal cost to enhance safety.

Techniques are well proven and a certain amount of similarity exists between manufacturer's systems. A pre-start warning generator unit is connected to the remote end of the communications system, this is necessary to improve the integrity of the system. Generally the circuitry in the unit is arranged so that the warning tones can only be generated if the supply voltage at the generator is healthy, this provides an assurance that the power lines are continuous throughout the system. The generated tone is transmitted along the audio line conductor and is normally monitored at the control end of the system, if the received tone is healthy there is a high probability that all the amplifiers on the system are, receiving the tones satisfactorily. This technique has been accepted on the basis that there are sufficient independent amplifier units to provide effective warning even in the event of one being faulty. Any faulty amplifier would be self-revealing under normal speech conditions and it is important on such systems that such faulty units are replaced. Theoretically, it would be better to monitor the sound output of each amplifier during pre-start warning but this would add considerable complexity and still leave the problem of fail-safe monitoring of the monitors. Such a system would inevitably lead to a less reliable system which would result in operational problems.

Transducer monitoring

For effective control of conveyors and haulages it is necessary to monitor a number of transducers, this protects both plant and men from the effect of running the system when conditions are potentially unsafe. The majority of protective transducers are in the form of segregated switch contacts, limit switches or thermal switches for example; and these need to be monitored in a manner that does not allow cable faults to confuse the switch state. This is a similar problem to that of signalling systems and the same solution is generally adopted. A semiconductor diode is fitted at the switch contacts and the presence of this is monitored by the control circuitry, this prevents a short circuited cable being confused with a closed transducer switch. The alternative signalling technique of providing a remote oscillator is generally inappropriate for monitoring transducers. The distances are usually short and the number of transducers generally involved would make the system insecure due to electrical pick-up both within the inter-connecting cables and the enclosure of the equipment.

The techniques used to monitor the remote diode vary considerably. The traditional method has been to use a 15V a.c. source and monitor the transducer contact and diode with a slugged relay. This can be made to work effectively but suffers from the difficulty of defining loop line parameters. Semiconductor monitoring is now extensively used, again generally powered from an i.s. a.c. source, either derived at mains frequency or generated from a d.c. supply, diode pump circuits can be used to monitor the effect of the remote diode or more recently the use of triacs has proved effective. A typical example of this is the F.M.S. unit, see Figure 3, which provides monitoring circuits for six transducers, each circuit operating a relay which has both FLP and I.S. contacts which enable the unit to be interfaced to a variety of control schemes.

Integrated Systems

Comprehensive control schemes for conveyors and haulages need a signalling system, a communication system, transducer monitoring and a control system. The integration of these sub-systems into a single unit has been commonplace for many years when used for the control of the face conveyor, but the less onerous requirements for roadway use has resulted in individually packaged sub-systems. This concept is changing and more integrated systems are being used for this purpose. This is perhaps mainly due to the issue of the NCB codes and rules document for conveyor drives which lays down minimum requirements for monitoring of conveyor drive heads and partly due to the increase in remote control of conveyors which again necessitates minimum requirements for the safe operation of conveyors. The availability of low cost integrated equipment will lead to a wide spread use of these systems which will greatly enhance the safe operation of conveyors in coal mines.

Typical of the latest generation of integrated control systems for conveyor control is the roadway pre-start warning unit, shown in Figure 4. This unit has an FLP compartment for housing power supplies and the relays which interface with a gate-end box, an I.S. chamber on top of the unit houses the signalling, communication, transducer monitoring and control circuitry.

The communication facility in the console provides all the features of stand-alone communication systems including an extension audio link for connection to the surface and the monitoring and control of pre-start warning for the controlled plant.

The signalling facility is selectable between the basic remote diode type of system and a more comprehensive remote generator system. This latter system incorporates key monitoring facilities whereas the basic system does not.

The transducer monitoring facilities are flexible in that there are three versions; the first provides monitoring of belt slip and belt motion; the second has a further eight transducer monitoring circuits which include brake monitoring, scoop monitoring (ATLC) and 2 channels which may be user defined if the conveyor is not manriding; the third version has a further 16 transducer inputs, 14 of which are user defined the other two are dedicated to smoke and methane monitoring.

The control panel on the I.S. compartment has the facilities to allow local control, the panel is fitted with start and stop buttons, test switches and selector switches for electrical and belt maintenance run selection are also provided. A number of visual indications are provided to display the status of the unit, fault conditions and the number of any locked-out signalling key. The number of locked-out signallings keys, plant faults and internal faults are displayed on a numerical indicator. If more than one numerical indication is required the display cycles such that all indications are displayed.

The unit can be configured for a particular installation by means of dual-in-line switches and links. Selection of features such as ATLC or direct drive, P130 or BZ1 pilot arrangement, number of transducers needs to be carried out, in addition to the adjustment of timers for belt slip, brake operation, scoop operation (ATLC), and P.S.W. times. Settings of the timers can be checked from the control panel by means of a test switch used in conjunction with the numerical display.

A remote stop/start unit fitted with display facilities can be used if control of the conveyor is required away from the siting of the console. This unit can be supplied in two forms each equipped with start and stop buttons; the first is equiped with four L.E.D. indicators to show the status of the system; the second has a more comprehensive display similar to that on the console. This is achieved by using a data link on the console which enables all the indications to be brought out on one pair of wires. This link conforms to part 1 of the draft British Standard for short-haul data links and could be used to connect the unit into a pit-wide data transmission system for both monitoring and control. At the present moment this sort of extension is limited by the availability of suitable equipment to accept this transmission standard.

Remote Control

The type of integrated unit described can provide all the requirements for remote control. The remote stop/start unit previously described would normally be situated at a point where the conveyor would still be considered to be 'locally' controlled, as shown in Figure 5a, however, there is no reason why such a unit should not be taken some distance from the conveyor to enable it to provide true remote control. This would allow a number of stop/start units for different conveyors to be installed at one point and thus be controlled by one man, see Figure 5b. This concept allows limited control and display facilities and a better solution would be to provide an underground control desk at the location concerned, see Figure 5c. This would also have the advantage of reducing cabling since a common data transmission system may be employed. Such a control desk is shown in Figure 6 and typically provides control of up to 12 control units either similar to the one described for a single pilot conveyor or more comprehensive units for dual pilot control of conveyors and other items of plant. The interconnection between the units would be by the short-haul data link used in both directions for monitoring and control. The underground desk provides many of the features found on surface control desks with the exception of the comprehensive displays on V.D.U.'s. A secondary short-haul data link on the underground control desk allows monitored information to be transmitted either directly to the surface or to a suitable pit-wide telemetry system.

Surface Control

Remote control of conveyors from the surface has been well established over the last few years with both the NCB MINOS system and systems from individual manufacturers. Such schemes have shown the potential benefit of remote control. Many of the present systems were developed some years ago and lack some of the flexibility that can be incorporated into modern systems, however there is a move towards improving these systems to incorporate distributed intelligence concepts along with modern transmission systems. Such improvements will provide sufficient flexibility to allow the installation of complex local control systems from different manufacturers which may subsequently be extended to the surface easily, see Figure 5d.

An added benefit is that full local control and monitoring facilities are retained in the event of a data transmission failure to the surface. Distributed intelligence concepts also allow the up-dating of log information on the surface when operation is restored.

Improvements in Productivity

In recent years heavy investment in the remote control and automation of coal clearance systems has demonstrated clearly that significant improvements can be made in productivity. Studies carried out have shown that very significant reductions in the starting times of conveyors can be achieved by computer and micro-processor based control systems.

A study carried out in one area of the N.C.B. showed that in the worst case it took a period of 17.5 minutes from a signal being given for the start of a conveyor, to that conveyor actually starting. Modern automatic systems can reduce this to a consistant time of just a few seconds. This sort of improvement is easily achievable and a typical reduction of from 15 - 30 minutes to a couple of minutes can be made when a number of conveyors are started in sequence. This advantage coupled with the rapid identification and logging of plant faults are valuable aids to increasing productivity and more effective mine management.

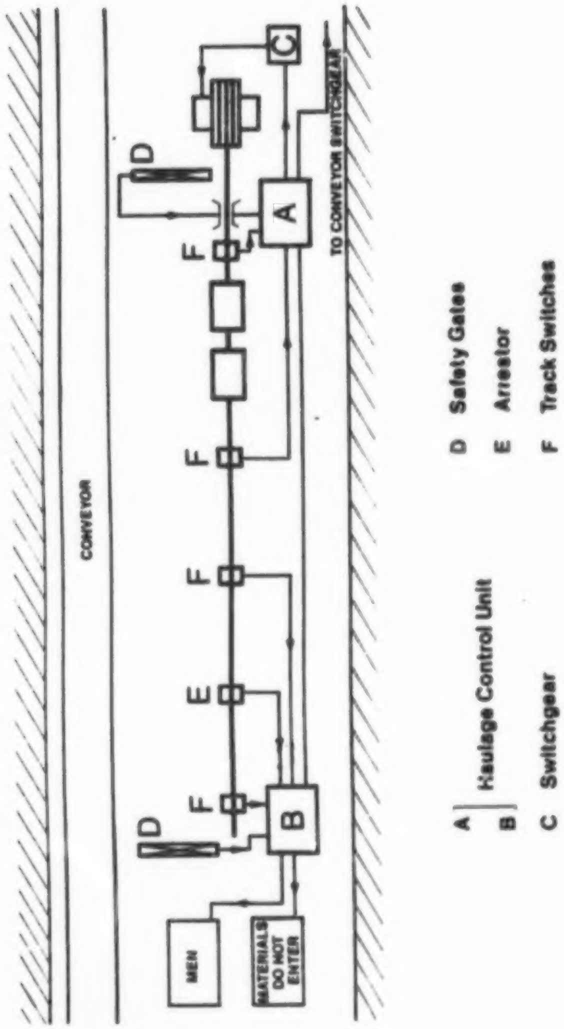
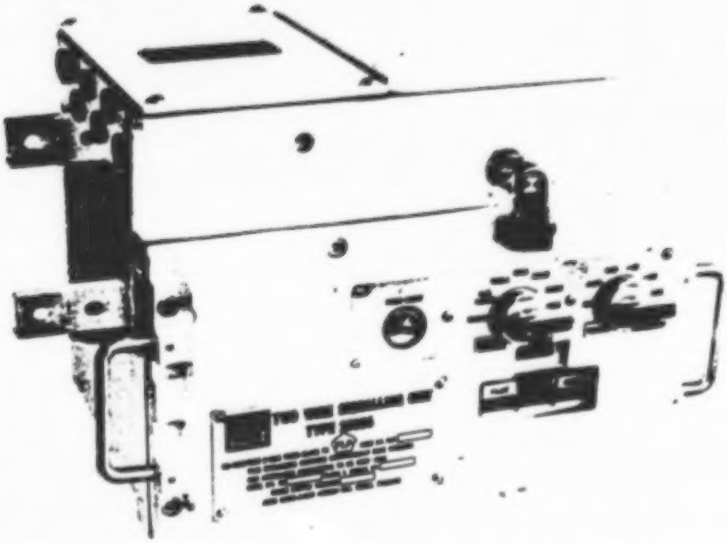
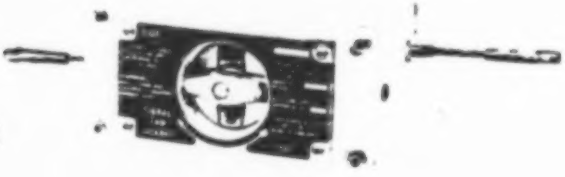


Fig. 1 - Despatch and Receive System (Simplified Diagram)



Control Console

Termination Unit



Key Unit

Fig. 2 - Signalling System Components

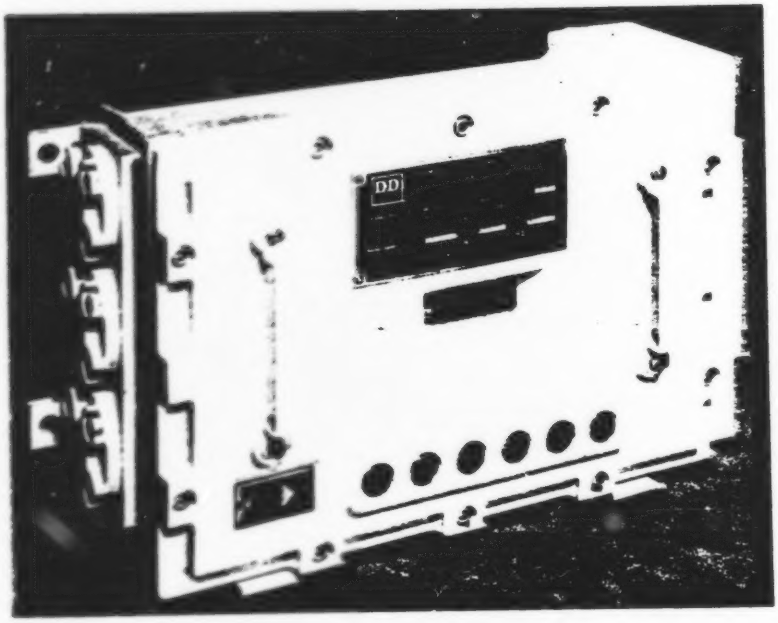


Fig. 3 - F.M.S. Transducer Monitoring Unit

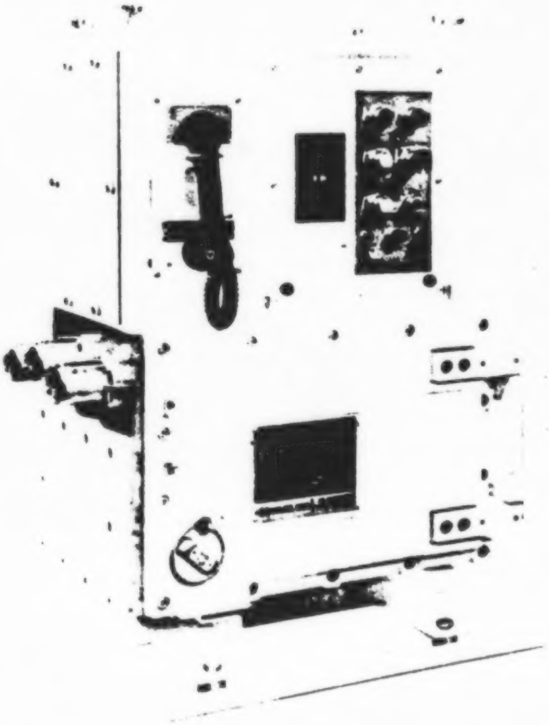
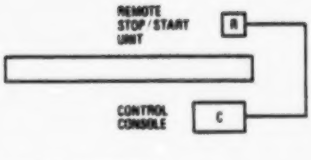
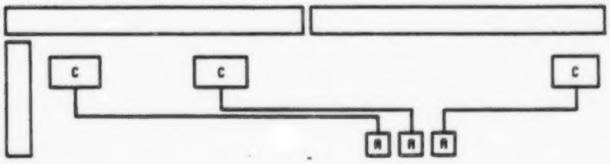


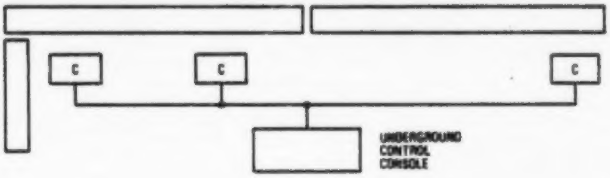
Fig. 4 - Roadway Pre-Start Warning Unit



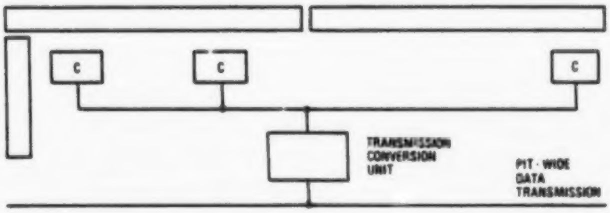
(a) Local control



(b) Remote control using separate cables



(c) Remote control using short-haul data transmission



(d) Remote control from surface

Fig. 5 - Conveyor Control Arrangements

Fig. 6 - Intrinsically Safe Underground Control Desk

New computer-controlled conveyor system at Rheinland combined mine

By Bergwerksdirektor Dr.-Ing. Hermann Boldt, Dipl.-Ing. Helmut Floh and Dipl.-Ing. Ulrich Techmer, Moers*

With the formation of the RAG steps were taken between 1970 and 1971 to create the Rheinland Combined Mine from the previously independent collieries of Pattberg, Rheinpreussen and Rossenray (Figure 1).

The most important technical undertaking associated with this amalgamation was the development of a combined conveyor system linking the collieries. This system represented the most efficient way of transporting and treating a daily r.o.m. output of between 40 000 and 45 000 t.

While Rossenray only had a temporary preparation plant, the haulage and preparation capacities of Pattberg 1 and Rheinpreussen 9 collieries were sufficient, after some extension work, to cope with an output of this size. On account of this fact the following projects were undertaken:
1. Excavation of a cross-cut between Pattberg and Rossenray collieries at the 885 m level.
2. Heading of an inclined stone-drift in the Pattberg area to connect the 885 m level with the 650 m level.
3. Installation of a belt haulage system which, in its final conceivable form, will consist of 24 conveyor belts (total length 24 km), two secondary bunkers upstream of the winding shafts and 10 r.o.m. bunkers (Figure 2).

With this system it will not be necessary to deepen the winding shafts at Pattberg 1 and Rheinpreussen 9 prior to the depletion of the deposits in the area.

PLANNING DETAILS

The following specifications were drawn up for the belt haulage system:

- To minimize contamination all belts must have a minimum width of 1200 mm.

- There must be a maximum degree of standardization of the technical features of the drives, delivery and return drums and intermediate structures.
- Belt manriding facilities must be set up where necessary and practical.
- The conveyor must have monitoring facilities for the following:
  - belt misalignment (monitoring devices installed in front of the delivery, drive and return drums as well as in front of and behind the intermediate feed points)
  - slip coefficient and belt speed
  - overflow in the transfer chute
  - longitudinal tears ('garland' monitoring devices used in conjunction with loop conductors vulcanized into the belt)
  - correct belt tension
  - position of the belt scraper
- Monitoring facilities must be provided for all gearboxes, couplings and brakes as well as for bearings on drive drums, bend rollers, and delivery and return drums. The following operating conditions must also be monitored; excess temperature, oil level in gearboxes, pressure level in air-pressure systems controlling the brakes, and finally the activation of the brakes themselves when the appropriate command is given.
- As laid down by the Chief Inspectorate of Mines of Northrhine-Westphalia (BVOSt) on 20th February 1970, stoppage and lock-out switches must be incorporated, at 100 m intervals, so that the system can be easily shut off by means of a pull wire and re-started again by a rapid switch release.
- A central belt control station must be set up so that, in view of the haulage distances involved, information can be transmitted regarding all shut-off and operating procedures.
- Loudspeaker units must be installed throughout the conveyor circuit so that maintenance personnel can be advised when necessary.

DESCRIPTION OF BELT HAULAGE SYSTEM

Belt layout

The types of belt used in the system (fabric or steel cable), together with the appropriate breaking strength, belt length, height of lift and resulting drive output, are all shown in the Table at the end of the paper.

Belt drives

The largest drive output of 4 x 560 kW is required for the inclined belt conveyor no. 11. The remaining outputs vary from 15, 33 and 100 kW to as much as 4 x 160 kW. Apart from belt no. 11, where the required operating voltage for the drive alone is 5000 v, all conveyors are driven by 500 v squirrel-cage induction motors. This unit can now be ordered from stock as the standard motor used by Ruhrkohle AG.

Couplings and brakes

The drives for inclined conveyor no. 11 feature couplings with ante-chambers which serve to limit the torque during the acceleration of the drive motors. This facility is in keeping with the safety requirements for steel-cable belts.

For drives comprising 100 to 160 kW motors a smooth start-up is achieved with hydrodynamic Voith couplings (supplied by Voith Turbo AG) by means of enlarged delay chambers. All brakes are of the disc type.

Gearboxes

For this purpose a new series of interchangeable gear units were developed by F.A. Flender and Westdeutsche Getriebewerke GmbH. The latter firm have also designed a new type of planetary gear unit capable of running the belts at crawler speed for checking purposes.

Intermediate structure

All intermediate structures are constructed from galvanized metal and are suspended from the roadway supports by chain attachments. At transfer points the intermediate structure has a garland layout, in accordance with the Saarberg system, so that it can be used for slit monitoring purposes.

Vibrating conveyor troughs

To permit correct feed regulation of the delivery and discharge volumes on inclined belt no. 11, which serves to connect two haulage levels, analogue-controlled vibrating conveyor troughs from AEG-Telefunken were installed in the conveying system to provide a continuous regulation of the transport volume up to 1500 t/h. Such a high regulating range is not required for the remaining conveyor troughs which, to date, have been operated with two specific discharge volumes.

Control and monitoring

The Geamatic 2000 i automatic system developed by AEG-Telefunken was chosen for the control and monitoring of the entire conveyor belt installation. This automatic system operates with the component systems Geatrans 21, a remote-control system in the audio-frequency range, Logistat GO i, the electronic control system, and FQM 200 i, a remote-control system operating in the high-frequency range (frequency-multiplex system with 200 channels). These three component systems are linked with one another and form a graded control structure. The advantage of this arrangement is then local control and monitoring procedures are carried out independently by the rapid processing unit while the central distribution of the transport volumes is undertaken by the slow processing unit. The majority of stoppages to belts or conveyor roads can be detected via these units by means of central volume distribution.

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*The first-named author is manager of Rheinland Combined Mine (BAG Niederrhein). The second author is member of the colliery management and the third author is head of the electrical section underground. Operating trials with the automatic system received financial backing from the Federal Minister for Research and Technology.

The control structure selected for the Rheinland Combined Mine, together with a plan of the Geamatic 2000 i automatic system, can be seen in Figure 3. Each belt is provided with a belt control unit (BSt 1,2,3 and 4 in Figure 3) which incorporates components from the three sub-systems, i.e. Geatrans 21, Logistat GO i and Geatrans FMQ 200 i. The remote-control system FQM 200 i transmits the signals from all the belt-monitoring devices on the appropriate belts to the logic system Logistat GO i. This logic system interprets the belt-monitoring information in accordance with the sequence control operation by first of all indicating the local switch-on and switch-off messages and then by returning these to the remote-control system FQM 200 i as 'on' or 'off' commands. These messages are then relayed to the remote-control system Geatrans 21 in a condensed form, and this system ensures that there is an exchange of information between the underground belt-control devices and the surface control room.

Four belt-control devices can be connected to a pair of telephone cables. Even when the line is not in operation the control sequence is maintained by the graded control structure on account of the fact that essential information travels independently from belt to belt via the remote-control system FQM 200 i.

The FQM 200 i remote-control system

200 channels of this remote-control system are available for each belt, these being used in the following way: 15 channels are constantly occupied for the interrogation of 50 stoppage and lock-out switches with one additional channel for switch-off; eight channels are provided for measured values, for example for the delivery flow of the vibrating conveyor troughs and the current input of the drive motors, while six channels are held for transmitting meter readings or other yes-no values.

Belt conveyors used in the Rheinland conveying system

Belt number	Location*	Capacity t/h	Centre distance m	Belt width m	Height of lift m	Belt speed m/s	Belt quality	Drive output kW
belt 1	R	1500	1650	1,2	2	2,5	Eb Pb 1250/1	2 x 132
belt 2	R	1500	1120	1,2	2	2,5	Eb Pb 1250/1	2 x 120
belt 3	R	1380/1800	55	1,4	0	0,4	St 1250	1 x 120
belt 4	R	1380/1800	12	1,4	2	2,0	St 1250	1 x 15
inclined belt 5	R	1380/1800	690	1,2	61	2,5	St 2000	3 x/4 x 160
belt 6	R	1380/1800	15	1,4	2	2,0	St 1250	1 x 15
belt 7	P	1380/1800	2610	1,2	3	2,5	St 1600	3 x/4 x 160
belt 8	P	1800	620	1,2	6	3,0	St 1000	2 x 100
belt 9	P	1800	2150	1,2	2	2,5	St 1600	3 x 160
belt 10	P	3000	585	1,6	7	3,0	St 1000	2 x 160
inclined belt 11	P	1850	1215	1,4	284.7	2,5/3,2	St 5400	4 x 560
belt 12	P	1380	1290	1,2	2	2,5	Eb Pb 1250/1	2 x 120
belt 13	P	1380	330	1,2	28,2	2,5	Eb Pb 1250/1	2 x 100
belt 14	P	–	2300	1,2	not yet installed			
belt 15	Rh	1380	2298	1,2	2	2,5	St 1600	3 x 160
belt 16	Rh	1380	225	1,2	2	2,5	Pz-630/2	2 x 33
belt 17	Rh	1380	15	1,2	2	2,5	Pz-630/2	1 x 33
belt 18	P	1380	200	1,2	- 21	2,5	Eb Pb 1250/1	1 x 100
belt 19	P	1380	180	1,2	35	2,5	Eb Pb 1250/1	2 x 100
belt 20	P	3000	20	1,5	0	0,5	–	2 x 63
belt 21	Rh	1380	190	1,2	45	2,5	Eb Pb 1250/1	2 x 132
belt 22	Rh	1500	16	1,2	0	2,5	Pz-630/2	1 x 33
belt 25	R	1500	450	1,2	2	2,5	Eb Pb 1250/1	1 x 100
belt 26	R	1500	1200	1,2	3	2,5	Eb Pb 1250/1	2 x 120

* R. Rossenray, P Pattberg, Rh Rheinpreussen

This leaves about 170 channels for the transmission of belt readings. Of these, each belt-control device has eight channels (redundancy) in the form of command channels for the control of four motors, four channels for the control of the associated braking systems, two channels for the crawler-speed motor, and a further channel for the possible installation of a mechanical belt-tensioning unit, a coupling filler device, a belt wiper and a spillage-clearance conveyor. The remaining 148 channels are used for 'sequence finished' signals from contactors and belt-monitoring points as well as from the vibrating conveyor troughs and the belt-weighing devices. The belt-control device on inclined conveyor no. 11 is almost fully utilized. This device is responsible for four motors, four brakes, the crawler drive gear, four vibrating conveyor troughs at the delivery end and the associated bunker messages which intervene in the control of the vibrating troughs and/or the inclined conveyor.

The Logistat GO i logic system

The control sequence is effected by means of the Logistat GO i control system. This involves electronic, i.e. contactless, control and there is no mechanically-moving switchgear. The projected switching circuit is constructed by the interconnection of the logical functions (AND, OR and storage functions) and long and short-term links, available on four different types of card, by wiring to the pins of the plug sockets by the wire-wrap principle. The switching circuit for the functional links is itself live, which means that the signals and the current move in the same direction. This helps eliminate spurious functions in the form of incorrect switching-in due to wire fracture or a short circuit in the input line.

Information on stoppages and operating procedures is displayed on three cards each having 26 light-emitting diodes at their output. A total of three magazines, each with 21 cards, is required for control and information purposes, with the input and output signals being relayed to the Geatrans 21 or FQM 200 i remote-control systems via opto-couplers.

The Geatrans 21 remote-control system

The Geatrans 21 remote-control system acts as a transmission system between the belt-control devices underground and the surface control room. Figure 4 shows the information and control message sent by this system. The information message comprises eight words to each 8 bits, with the result that 64 yes-no signals, 8 measured values to each 8 bits, 16 meter readings to each 4 bits or any combination of these can be transmitted at any one time. The command message consists of four words and permits the transmission of 128 commands. Reference input commands, like the information message, are composed of eight words to each 8 bits.

The following data from each belt must be sent to the surface control room:

The running conditions of the belt.

The 'clear' or 'lock out' control from the surface control room.

The type of operation selected, e.g. fully automatic, part-automatic, motor-brakes individual operation, repairs, off.

The fault information - such as belt-misalignment at discharge, belt-misalignment at central feed, belt-misalignment at drive, belt-misalignment at return, scraper at discharge, scraper at drive, scraper at central feed, scraper at return, bearing temperature at drum drive, bearing temperature at drum discharge, bearing temperature at drum return, belt tensioning unit, overflow, defective motor, gearbox bearing temperature, gearbox oil temperature, brake temperature, coupling temperature, gearbox oil level, temperature of motor windings, brake-release monitor, belt slip, start-up, FQM circuit monitoring, belt tear at return, belt tear at central feed, compressed-air status, collective fault information, simulation of a shut-down switch, numbers of activated shut-down switches.

In addition to this, data is transmitted to the surface control room regarding up to seven bunker filling levels, the running and stoppage conditions of the vibrating conveyor troughs, the vibrating range and the measured values and quantities from the belt weighers. The control room commands the clear or lock-out signal for the belts and vibrating troughs and controls the on-off commands for belt no. 1 in the haulage road as well as the on-off and throughflow commands for the vibrating conveyor troughs or analogue reference input. For each belt there must, therefore, be available at least two complete data messages, a command message for 8 to 32 commands and, if necessary, a reference input channel for the analogue-controlled vibrating troughs. The Rheinland system is of the frequency-time multiplex type and has 12 channels in the audio-frequency range between 800 and 3200 Hz at a telegraph line speed of 50 baud. With this system four belt-control devices can be adapted to one pair of telephone cables. This allows the transmission of 512 items of useful information in the direction of communication as well as 24 reference input commands for each 8 bits and 128 on-off commands. As each message, including the start, stop and parity bits and the synchronization pause, is a total of 108 bits long, this means that at a telegraph line speed of 50 baud each piece of information arrives after 2.16 s. 4-word command messages require 48 characters and are consequently dispatched in 960 ms.

PREPARING THE SYSTEM FOR OPERATION

When drawing up the design of the system it was decided that all equipment destined for underground use would be assembled in the surface workshops and tested, under simulated conditions, for reliability and correct operation prior to installation underground. This system, which has been rarely used up until now, is shown in Figure 5 undergoing functional testing of the emergency and belt-misalignment switches. All emergency and belt-misalignment switches fitted to the 3000 m-long conveyor were assembled, in compact form, in the surface workshops and subsequently wired and subjected to functional trials via the associated belt control device. Only after these tests did the installation receive authorization for underground installation. Similar tests were conducted on the belt control devices, the emergency control equipment which comes into operation automatically should the main control system fail, the rotating temperature monitors for couplings and brakes and also the belt-slip and belt-speed monitoring units.

The switchgear comprised three self-contained operating units. After the surface trials each of these were taken underground for installation as a separate transport unit, namely:

a) The protected cable switchgear (Figure 6 - left) as the input station with complete mains protection for the downstream contactor station.

b) Contactor station (Figure 6 - centre) with standard equipment for short-circuit, overload and earth-connection protection for the 3 motors (up to 160 kW), 3 brake-release contactors, and one contactor each for the belt wiper and spillage-clearance conveyor.

c) The belt control device (Figure 6 - right) which collects the signals from the peripheral belt monitoring units, interprets these via the GO i logistat and then relays them via the Geatrans 21 system. The belt control device and all sub-stations of the FQM 200 i remote-control system are all composed of plug-in connections and can, therefore, be installed and dismantled with ease.

The additional expenditure obviously incurred as a result of the surface tests enabled the equipment to be inspected within a compact area with the result that defects in individual components could be traced quickly and cheaply and the faulty component replaced without difficulty.

BELT MONITORING SYSTEMS

Stoppage and lock-out system

Each belt control device is provided with a stoppage and lock-out system (Figure 7). This consists basically of a rope pull switch which acts as an emergency switch enabling the belt to be stopped immediately either by those riding on it or by those on foot in the roadway. Figure 7 shows an emergency switch system for top and bottom belts with loudspeaker facilities. Stoppage switches are installed at the belt boarding and alighting points and these can be activated by 'untrained' personnel riding on the belt. If the alighting point is passed the belt is brought to a halt by an overtravel switch.

Belt misalignment and garland feed control

The belt misalignment monitoring system is a well-known technique in the mining industry.

The garland feed comprises suspended idlers which intensify the troughing of the belt and ensure a central delivery of the product. Both the garland rollers and the lateral guide plates are moveable and activate the monitor switch if the material being transported becomes wedged between the belt and the guide plate or if the belt is pierced by a drill rod or similar item.

Overtravel control

Most overtravel control systems consist of magnetic switches, supplied by Dr. H. Tiefenbach GmbH & Co. KG, which are activated by moving rubber aprons. The necessary contacts are enclosed in protective gas and thereby conform to safety regulations. Siemens infrared light barriers are also used to assist the geometrical layout of the belt transfer points.

The gearbox oil level is controlled by float switches while air pressure is monitored by a pressure switch. The maintenance-free belt tensioning system is controlled by magnetic switches which register the position of the counterweights.

The temperature of the drum and gearbox bearings is controlled by rod-type thermal transducers which screw into drillings in the machine parts. The monitoring element is a thermistor which has direct control of a frequency-multiplex transmitter and sends a cut-out command at 85°C. The switch-off temperature in this case varies by ± 3°C.

Three series-connected thermal transducers were developed for monitoring the temperature of the gearbox bearings. Together these transducers control a transmitter which triggers cut-out at a temperature of 90 to 105°C.

Belt-slip control is based on a contactless system in which the circumferential speed of a driving drum (the drive drum) is compared electrically with a driven drum (the bend pulley). The impulses are provided by cam plates which are mounted on the drums being monitored.

Speed control is based on a similar system which also features contactless operation.

The thermal control system for disc brakes and couplings is likewise a contactless system. A rise in temperature causes a ferrite bar magnet, which is built into the disc or coupling, to lose its magnetism. This means that the initiator and interpreting card receive no impulses and interpret this as a cut-out signal.

All steel-cable belts use the contactless slit monitoring device developed by Montan-Forschung Dr. Hans Ziller. The delivery contract for conveyor belting stipulates that one loop conductor must be ordered for each roll of belt; when installed the distance between the loops varies from 80 to 120 m.

Bunker-level monitoring

Bunker levels are also controlled by a contactless monitoring system which consists of Funker + Huster radio-active isotope barriers. The following marker levels may be provided where possible: bunker max., bunker pre-max., bunker ¾-full, bunker ½-full, bunker ¼-full, bunker pre-min. and bunker min.

Four of these values are used directly for control purposes: when the 'bunker max.' level is reached the delivery belt is switched off; this belt can be started up again when the level falls below 'bunker pre-max.', i.e. when a sufficient volume has been drawn from the bunker and belt start-up guarantees a longer conveying time; when the 'bunker min.' level is reached the off take vibrating conveyor trough is switched off immediately so that the trough itself is still protected by a cushion of coal; and finally, when the 'bunker pre-min.' level is reached the conveyor trough is started-up once again.

Throughflow control

Instantaneous throughflow can be monitored by means of the oscillation range of the vibrating troughs on account of the fact that the oscillating range is representative of the transport volume (Figure 8). However, frequent changes in the settings, either manually or by computer, mean that this technique cannot be applied when an accurate survey is required of the throughflow in tonnes per hour or per shift.

The current input to the drive motors can also be used as a criterion for the load status of the belt. Admittedly this principle is only used to prevent the possibility of overloading on the inclined belt, an important factor in a computer-controlled conveying system.

It is, therefore, planned to install Eickhoff intrinsically-safe belt weighers for throughflow monitoring. Successful trials have already been carried out with a prototype which has been adapted to operate with the Geamatic system. These weighers provide the remote-transmission system with data on the throughflow in t/h and in this way supply the comparative value for the actual-value feedback from the corresponding vibrating conveyor trough. In addition, the total delivered tonnage is added up, locally displayed and transmitted to the surface control room. The local flow meters, together with those in the control room, can be cleared by command at the pre-determined time (beginning and end of the conveying shift).

TYPES OF OPERATION

With this control and monitoring system it is possible to select four different types of operation via a pre-selection switch on the belt control instrument: automatic conveying, part-automatic conveying, repair and crawler speed. The motors and brakes can also be operated individually for testing and repair work.

When the belts in a haulage road are on automatic operation the control operator in the surface control room can switch to computer control since with this type of operation the underground belt control instruments supply all the signals which are required. A description of this type of operation will appear later.

Automatic conveying

Automatic conveying is initiated when the first belt in a haulage road receives the command 'switch on' from the remote-control system Geatrans 21 in the form of an impulse message from the surface control room. This command is received and stored by the logic system Logistat GO i. The command is carried out if, over a certain period (up to 5 mins), no belt start-up has occurred and there is no impending cut-out from a belt-monitoring unit; start-up is preceded by a characteristic warning signal transmitted along the belt conveyor circuit to the intercom systems. During the pre-warning period an advance command, with a variable time delay, is sent to the next belt downstream so that the latter can activate its warning signal before the preceding belt has reached full speed. The switch-on command is only undertaken when the preceding belt has attained full speed, this being measured by the belt-speed monitoring system. After the pre-start warning the motors are started up in staggered fashion (variable). The brakes are released in series in accordance with the motors.

The cut-out command is also sent from the surface control room via the Geatrans 21 remote-control system; it is again stored by the logic system and relayed to the next downstream belt by the Geatrans FQM 200 i remote-control system. Here the switch-off command is again stored and sent to the subsequent belt via the local FQM system. In this way the belt installation is brought to a halt in a sequence which is contrary to that of the switch-on procedure.

This type of cut-out system is known as 'guided cut-out' and can be delayed by time links in accordance with belt braking times in such a way that during the stoppage procedure no spillage occurs in the transfer chutes. When the cut-out command is given the brakes are first applied and then the belt motors are switched off in a time-variable sequence. The surface control room, therefore, determines the operational stoppages while the belt-monitoring systems control the cut-out facility. Exceptions to this rule are the switch-off commands from the stoppage and lock-out systems and from the over-travel and slit-monitoring devices.

Part-automatic conveying

All monitoring systems are in operation during part-automatic conveying. The switch-on command from the preceding belt is not accepted, however, since with this type of operation switch-on is carried out manually. A selector switch on the belt-control instrument determines whether or not the 'on' key on the belt-control instrument, or on the discharge drum, can be cut in. The 'off' keys at the two possible switch-on points remain constantly operative and when activated likewise produce a guided cut-out.

Repair

When the system is operating on 'repair' the only monitoring systems which remain operative are the motor excess temperature control and the stoppage and cut-out devices. Switch-on is effected in the same way as for part-automatic conveying. The switch-on commands to the next downstream belt are locked-out.

Crawler speed

For operating at crawler speed, with the belt running at a controlled speed of 0.5 m/s, the switch-on command is sent to the crawler-speed contactor by a key on the conveyor, the signal being transmitted via the FQM 200 i system.

The belt motors are locked-out via the Logistat GO i system, which also switches on the crawler motor and releases the brakes. For crawler-speed operation it is essential that there is no possibility of a cut-out command from the stoppage and lock-out devices.

SURFACE CONTROL ROOM

The belt conveying circuit, including bunkers and vibrating troughs, is displayed on a luminous-circuit diagram (Figure 9, cf. also Figure 2) which enables the running conditions of the conveyor system to be examined at any time. Faults on the belt conveyor are signalled by a flashing red light, while a belt which has been cut-out is represented by a permanent red light. By means of control switches it is possible to release or lock-out each belt conveyor and each vibrating conveyor trough throughout the entire system. Bunker levels are displayed by red light-emitting diodes (for full and empty) and by green light-emitting diodes (for up to 5 intermediate filler levels).

The belts in each of the haulage roads can be switched on and off manually from the operator's panel (Figure 10). From here it is also possible to adjust the throughflow in the vibrating conveyor troughs so that the individual transfer volumes can be adapted to suit the capacities of the various belts and winding shafts. In a special display area (Figure 10 - left) green light-emitting diodes are used to indicate position of the 'operation control' selector switch on each belt control instrument. Fault information for each belt can be read-off by operating the keys on 29 red light-emitting diodes. A telecommunication system enables the surface control room to communicate with loudspeaker stations which are installed every 100 m along the conveyor circuit. Each individual station can be contacted independently throughout the system of belts and conveyor roads. The surface control room can also set up a telephone link between the individual belts.

The operator controls of the control panel become inoperative if a conveyor road is switched to computer control by means of a selector switch. In this case the 'clear' signals and the 'running' and 'fault' signals on the luminous-circuit diagram, as well as on the control panel, are retained for visual observation, as are the throughflow displays relating to the belts and the vibrating conveyor troughs.

The remote-control centre, which is housed in five remote-control cabinets, forms the nucleus of the control room. These cabinets contain all the components and equipment necessary for the reception of signals and measurement and metered data as well as for transmitting commands and reference input to the analogue-controlled vibrating conveyor troughs. When fully utilized the remote-control centre can handle simultaneously a total of 640 commands, 160 reference input items and 2560 signals.

The print-out computer is linked to the remote-control centre. This computer draws up the immediate-printout programme with 'on' and 'off' data relating to belts and vibrating troughs, the nature and location of faults, the hourly programme with individual throughput values and totals taken from the belt weighers, the bunker filler levels and totals and also data relating to the individual belt conveyors. The 24-hour programme is eventually drawn up from the sum of all the hourly programmes.

The AEG 80-20/4 control computer is connected to the remote-control centre by relay-digital input and output cards as well as by an analogue output card. This control computer provides the conveyor system with its computer-control facility.

COMPUTER-CONTROL FACILITY

The following main tasks were assigned to the control-computer programme:

a) The capacities of Pattberg 1 and Rheinpreussen 9 winding shafts were to be fully utilized.

b) Inclined conveyor no. 11, with its large drive output of 4 x 560 kW, was to be put on continuous operation as much as possible.

The control computer was programmed with the assistance of the control package AS80 which offers a high degree of ease for programming and line-up as well as for on-line changes and expansion.

To ensure continuous running of the inclined conveyor connecting the haulage levels, the computer controls the load volume through the four vibrating troughs in such a way that it corresponds with the off-take volume from the troughs which supply the roadway conveyors feeding the Pattberg and Rheinpreussen winding shafts. To do this reference input for the off-take vibrating conveyor troughs is fed to the computer in a conversational programme. From this the computer automatically determines the reference input for the vibrating conveyor troughs at the inclined conveyor delivery point. Delivery is halted by the computer whenever there is a stoppage on the conveyors feeding the Pattberg and Rheinpreussen shafts. If there is insufficient coal in the distribution bunker, the computer increases the delivery volume to the maximum permissible load. If there is excess coal in the distribution bunker the computer reduces the delivery volume and increases the rate of discharge from the vibrating conveyor troughs feeding the main winding shafts.

To minimize repair costs the roadway conveyors which lead to the main winding shafts and feed the main bunkers take priority over those which feed the secondary bunkers. On account of this the computer only switches on the belts feeding the secondary bunker shortly before the 'full' level is reached and then actuates the appropriate reversing valve when the bunker registers 'full' without interrupting the conveying operation.

Optimum throughput is achieved in Pattberg 1 shaft by the fact that the volume of coal fed to the main bunker, which only holds 160 m^3, corresponds with the instantaneous capacity of the winding machine. The optimum volume requirement is determined by calculating a so-called 'by-pass' load. An insufficient volume of coal on the belt conveyor is brought to the optimum load level by switching on the vibrating troughs below the secondary bunker. Both troughs can be adjusted to two different volume settings. At Pattberg 1 shaft, belt-conveying takes priority over tub haulage, which accounts for a smaller transport volume, while at Rheinpreussen 9 shaft tub-haulage currently takes priority over belt-conveying.

At the present time there is computer-control operation on the 650 m level and on the belt in the inclined stone-drift linking the two levels. It is soon planned to incorporate the remaining part of the system to optimize conveying on the 885 m level. The aim of the optimization project is to have continuous running on all conveyors. This is only possible if the total volume of coal conveyed on the 885 m level corresponds with the volume being taken out by inclined conveyor no. 11. The relatively large shaft bunkers at Rossenray (each 1500 t capacity) are used for regulating the volume throughflow for the conveying system. Information to be used as reference input is obtained from the following data:

1. The volume of coal transported by belt is added up by the computer.

2. The coal delivered by the various feed systems (e.g. staple-pit chutes) is calculated from the running time of the shearer-loaders or coal ploughs. This is made possible by the fact that one knows the winning capacities of the individual winning installations in the districts.

Optimization calculations can be made at intervals of one minute - each giving accurate results for the subsequent 15 minutes.

SUMMARY

The two-level belt conveyor system at Rheinland combined mine currently consists of 17 main belts (total length 16 km), 8 r.o.m. bunkers and 10 vibrating conveyor troughs. The system is monitored by the Geamatic 2000 i automatic system and controlled from the surface control room. The automatic system incorporates the Geatrans 21 and Geatrans FOM 200 i remote-control systems and the Logistat GO i logic system. The computer-control link to the system enables inclined conveyor no. 11, which connects the haulage levels, to be run on a continuous basis and allows Pattberg 1 and Rheinpreussen 9 winding shafts to be fully utilized, even when there is a variable distribution of throughflow.

The development and installation of the control and monitoring system described here were backed up by research funds. The success obtained with this system suggested that additional belt installations, which are used in in-seam roadways for feeding the main conveying system, could be gradually incorporated into the control and monitoring system. Such a move would provide early detection of belt faults and thereby improve safety in the in-seam conveying areas; in addition, it would benefit repair duties by providing more precise information and would also make for a more efficient utilization of the inbye conveyors due to the application of the computer-control facility.

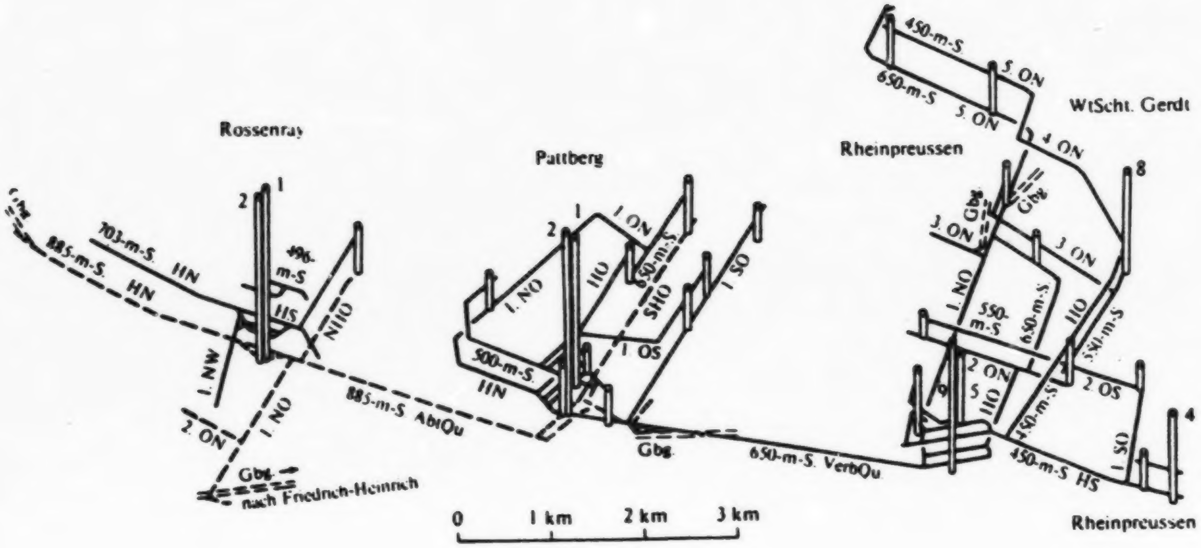
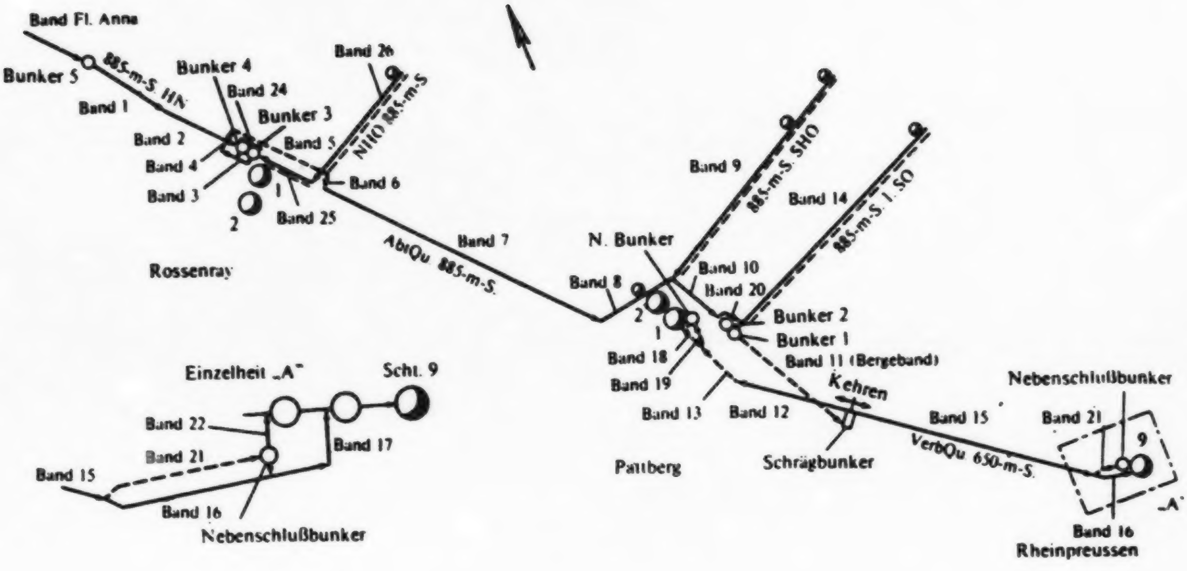
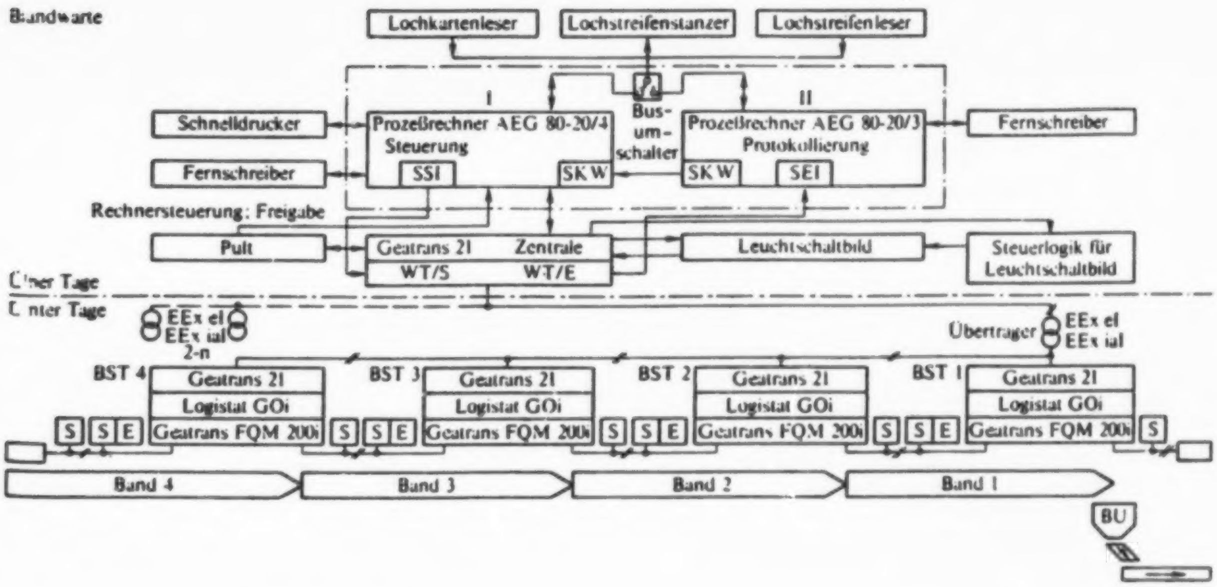


Figure 1. Isometric diagram of the Rheinland Combined Mine showing the Pattberg, Rheinpreussen and Rossenray shafts.



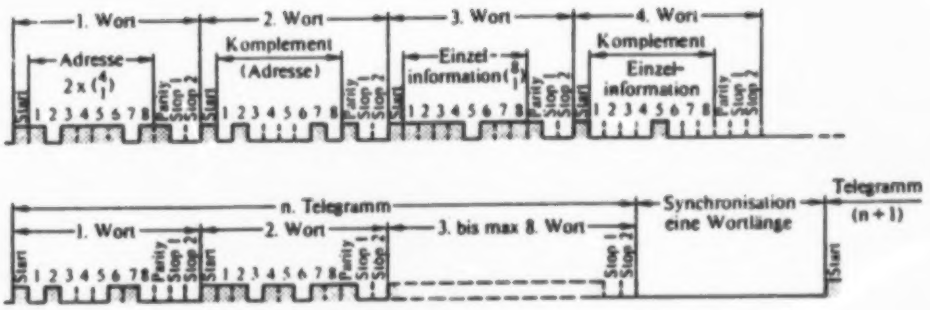
Band	belt
Bunker	bunker
Fl. Anna	Anna seam
Scht.	shaft
Einzelheit A	detail diagram of 'A'
Nebenschlussbunker	secondary bunker
885-m-S	885 m level
AbtQu.	district cross-cut
Schrägbunker	inclined bunker
VerbQu.	connecting cross-cut
Kehren	turn-round point

Figure 2. The Rheinland conveyor system.



Bandwarte	surface control room
Lochkartenleser	punched-card reader
Lochstreifenstanzer	tape puncher
Lochstreifenleser	punched-tape reader
Schnelldrucker	high-speed printer
Fernschreiber	teleprinter
Prozessrechner	process-control computer
Steuerung	control
Busumschalter	bus change-over switch
Protokollierung	print-out recording
Rechnersteuerung	computer control
Freigabe	clearance
Pult	control panel
Zentrale	control station
Leuchtschaltbild	luminous-circuit diagram
Steuerlogik für Leucht-schaltbild	control logic for luminous-circuit diagram
Ober Tage	surface
Unter Tage	underground
Ubertrager	transducers
Band	belt
BU	bunker

Figure 3. Systematic representation of the Geamatic 2000 i automatic-control system used by the Rheinland Combined Mine conveyor circuit.



Wort	word
Adresse	address
Komplement	complement
Einzelinformation	information item
Telegramm	telegram message
3 bix max 8 Wort	3 to max. 8 words
Synchronisation	synchronisation
eine Wortlänge	one word length

Figure 4. Layout of telegram message from the Geatrans 21 remote-control system showing command message (top) and message for signals, metered values and measured values.

Figure 5. Surface tests with the emergency and belt-misalignment switch.

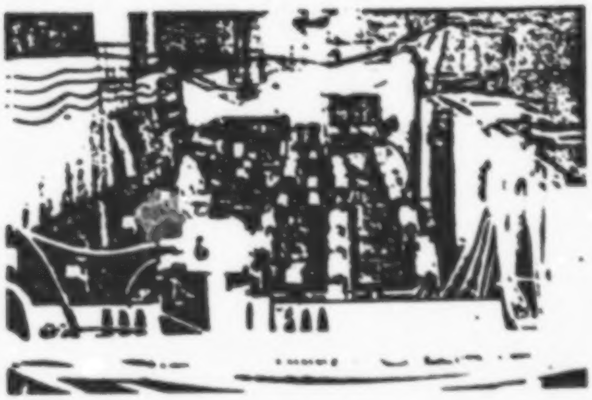


Figure 6. Protected cable switchgear, contactor station and belt-control instrument.

Figure 7. Stoppage and lock-out device.

Figure 8. Vibrating conveyor troughs.

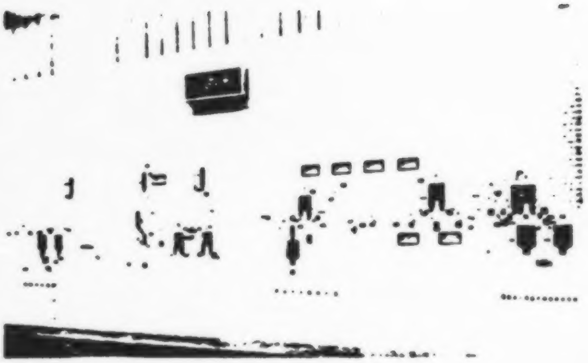


Figure 9. Luminous-circuit diagram in the surface control room.

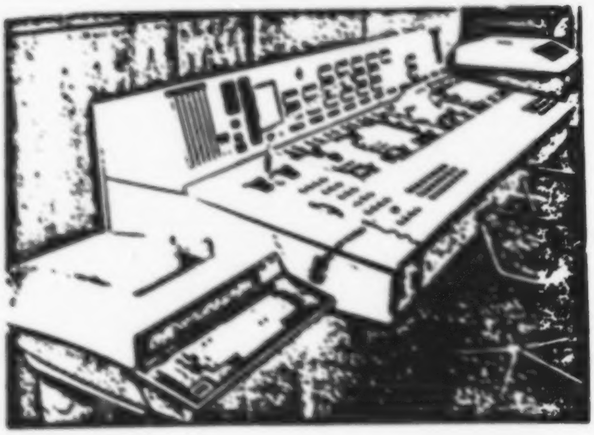


Figure 10. Operator's panel in the surface control room.

POOR
QUALITY
ORIGINAL